116 5-19-81

(2)

2h. 2655

SERI/TR-742-784

March 1981

R4435

Evaluation of Conventional Electric-Power-Generating-Industry Quality-Assurance and Reliability Practices

R. T. Anderson
H. A. Lauffenburger

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Operated for the
U.S. Department of Energy
under Contract No. EG-77-C-01-4042

DISCLAIMER

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:
Microfiche $3.00
Printed Copy $6.50

NOTICE

SERI/TR-742-784
UC CATEGORY: UC-97d

MASTER

EVALUATION OF CONVENTIONAL ELECTRIC-POWER-GENERATING-INDUSTRY QUALITY-ASSURANCE AND RELIABILITY PRACTICES

R. T. ANDERSON
H. A. LAUFFENBURGER

MARCH 1981

PREPARED UNDER TASK NO. 1092.00

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Prepared for the
U.S. Department of Energy
Contract No. EG-77-C-01-4042

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

PREFACE

The work described herein was performed by the SERI Quality Assurance and Standards (QAS) Branch, Planning Applications and Impacts Division as part of Task 1092: Development of Performance Criteria and Test Standards for Photovoltaic Systems. Gary R. Nuss provided guidance and direction in planning the study and preparing this report. Ronald T. Anderson, Reliability Technology Associates, was a major participant in conducting the study and preparing the report.

The study evaluated the quality assurance and reliability activities associated with the development, production, installation, and operation of electric power generating systems to ascertain approaches and methods appropriate for photovoltaic electric energy systems. This report describes study findings and provides recommendations for establishing photovoltaic system Quality Assurance and Reliability methods.

The authors are indebted to the many organizations and individuals who willingly provided information, documentation, and, most importantly, their time for in-depth technical discussions on the goals, activities, and accomplishments of their respective functions. We especially acknowledge the cooperation of Dr. Safron S. Canja, of the Department of Energy for his time and patience in describing the DOE Fossil Energy Performance Assurance Program and Fossil Energy Event Data System, offering study guidance, identifying knowledgeable individuals, and for his constructive review of the draft manuscript.

Gary R. Nuss, Chief
Quality Assurance and Standards Branch

Approved for

SOLAR ENERGY RESEARCH INSTITUTE

Jon M. Veigel, Manager
Planning, Applications and Impacts Division

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

SUMMARY

OBJECTIVE

This study was conducted to determine the techniques and practices utilized in an allied industry (electric power generation) that might serve as a baseline for formulating Quality Assurance and Reliability (QA&R) procedures for photovoltaic solar energy systems. The study results provide direct near-term input for establishing validation methods as part of the SERI performance criteria and test standards development task.

DISCUSSION

The determination and demonstration of quality and reliability are essential elements in the commercial acceptance of photovoltaic solar energy systems. Consistent achievement of satisfactory levels of quality and reliability requires that positive actions be instituted as an integral part of system design, manufacturing, and installation. Although QA&R program basics are well established, specific program activities are governed by the characteristics and needs of the intended application and its functional environment.

Information and data were obtained from representatives of the utilities, architect/engineer (AE) firms, manufacturers, industry associations, and others active in QA&R. Discussion questions dealt with scope, organization, procedures, methods, effectiveness, and terminology of practices currently being applied. Findings were reduced, organized, and evaluated with recommendations formulated relative to the potential applicability of specific approaches and practices to photovoltaic (PV) systems and components. Study results, conclusions, and recommended QA&R activities for the PV program are presented in this report.

Reliable power has been achieved over the years by the electric power industry primarily through the use of redundant components, subsystems, and generating units. Due to the increased cost of replacement, operation, and maintenance, it became apparent several years ago that the reliability of individual generating units needed significant improvement. The practices and programs being developed and implemented by the conventional electric power industry thus are intended to reduce costs by focusing on increasing productivity through reduced unit downtime.

All segments of the industry are aware of the importance of QA&R and are actively addressing QA&R. The formality, scope, and rigor of the activities vary greatly with each organization and its functional responsibility. The more aggressive organizations are applying disciplined analysis methods, performing rigorous tests, preparing and imposing Reliability, Availability, and Maintainability (RAM) specifications, performing supplier audits and surveillance, implementing data recovery and feedback systems, and conducting failure analyses. Many of the practices can be directly applied or readily adapted or modified to meet the needs of the photovoltaic QA&R program.

Utilities generally have formal QA&R departments with direct responsibility for performing vendor audits and surveillance, establishing and implementing a data recovery and feedback system, performing failure analyses, and determining requirements for inclusion in generating unit and equipment procurement specifications. The utilities are using, at least in part, QA&R methods to specify and control the reliability of operating power generating units and equipment and as part of the design process for new or replacement equipment and components.

AE firms address reliability and quality as an integral part of the plant design and system specification process. They direct much effort toward incorporating specific QA&R requirements (sometimes quantitative) into their plans, drawings, and specifications.

Major hardware manufacturers generally maintain and implement a comprehensive program with sizeable QA&R organizations and formal procedural manuals that emphasize QA activities, but with increasing concern for reliability. Many organizations are commonly performing reliability prediction and assessment, failure mode and effect analysis (FMEA), and design review.

The utility and trade associations, such as the Edison Electric Institute/National Electric Reliability Council (EEI/NERC) and Electric Power Research Institute (EPRI), support the utilities and their AE firms and manufacturers by providing research, authoritative information and data, definitions, procedures and guidelines, as well as providing an essential forum for technical exchange.

In addition, DOE is developing performance assurance guidelines including a Fossil Energy Equipment Data System (FEEDS) for application to fossil energy development, demonstration, and pilot projects. These guidelines cover reliability, maintainability, availability, quality assurance, configuration management, life-cycle cost, and system safety and are applicable throughout the design, construction, procurement, and operation and maintenance of complex power plants.

CONCLUSIONS AND RECOMMENDATIONS

Some specific practices and programs evaluated during the study and considered particularly applicable to the PV program are:

- Ontario Hydro's specification approach and reliability program matrix
- Bonneville Power Administration's life-cycle cost (LCC)/performance approach and surveillance and quality survey report
- Consolidated Edison's quality assurance level matrix
- Florida Power and Light's reliability methodology and unit availability report
- Institute of Electrical and Electronic Engineers (IEEE) and EEI/NERC QA&R definitions (selected)
- EEI/NERC, EPRI, and DOE data recovery and feedback methods (i.e., data forms, procedures, data management schemes, and output reporting formats).

Major payoffs (in terms of improved reliability) can be expected from the immediate adaptation and implementation of certain QA&R practices (e.g., manufacturer's audits) into the PV field test and applications programs, then following with longer range provisions specifically developed or tailored to meet the needs of the broader PV program.

Recommendations for developing an effective and viable PV QA&R program focus on:

- Adapting applicable electric power industry QA&R practices and techniques;
- Integrating QA&R initiatives currently being pursued within the PV program;

- Developing additional practices and techniques as may be necessary to augment above;
- Establishing a dedicated reliability data recovery and feedback system;
- Continuing improvement of the practices, techniques, and data recovery system; and
- Continuing high level management attention.

Subsequent sections of this report expand on the results and recommendations summarized above.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1.0

INTRODUCTION

This study of the conventional electric power generating industry's quality assurance and reliability practices was conducted to establish a baseline for formulating approaches, methods, and techniques to assure the quality and long-term reliability of photovoltaic solar energy systems. This work is part of the validation methodologies development task of the SERI performance criteria and test standards development project (Nuss 1979).

1.1 BACKGROUND

Widespread public acceptance of photovoltaic (PV) solar energy generating systems requires more than the ability to produce the desired electric power economically; the systems must continue to produce power reliably over extended periods. Over the years, electric utilities have established a record of continuous, relatively trouble-free service. Any alternate power source will be judged against this norm by potential customers. Consequently, broad commercialization of PV systems depends heavily on developing and producing high quality systems, subsystems, and component hardware (and software to some extent) that are reliable and can be economically maintained. Past experience with hardware systems, particularly complex aerospace systems and, recently, modern microcomputing systems, has shown that disciplined quality assurance and reliability control as an integral part of development and demonstration are essential for achieving production quality and operational reliability.

This study was performed to establish a baseline on which to formulate PV quality assurance and reliability (QA&R) efforts. Because of its long history of servicing the electric power market, the QA&R methods, standards, techniques, and procedures employed by the conventional electric power generating industry were evaluated. Input was requested from all segments of the industry, including operating utilities, architect-engineer (AE) firms, power generating system and component manufacturers, utility associations (such as the Electric Power Research Institute and the Edison Electric Institute), the Department of Energy (DOE), and other related technical societies and trade associations. Selected reports from DOE, conferences, symposia, technical journals, etc., were also collected and evaluated. The information was screened and analyzed, and recommendations were formulated, based on the findings, for developing a photovoltaic QA&R program.

1.2 STUDY OBJECTIVE

The objective of this study was to establish a thorough understanding of the QA&R practices that the electric power generating industry found to be most effective in achieving high hardware reliability and electric power generation system availability. The results and recommendations of this study are intended to be used by the Solar Energy Research Institute (SERI) as a basis for developing long-term QA&R requirements and plans for PV power generating systems. Further, the results provide direct input into the following near-term SERI activities that are part of the validation methodologies development task of the PV performance criteria and test standards program:

- Preparation of a glossary of QA&R terms applicable to solar energy systems
- Establishment of realistic QA&R testing procedures and performance standards for solar energy systems and components
- Development of a data analysis procedure for solar energy systems' reliability, maintainability, availability, and quality assurance measures
- Development of an efficient and useful solar energy system data recovery, analysis, and feedback system
- Performance of comparative reliability assessments
- Development of reliability prediction models and analysis tools
- Establishment of QA&R program provisions, requirements, and validation procedures.

The study was limited to the power generating system and its components, excluding transmission and distribution. It concentrated on nonnuclear energy driven generating systems because the feeling was that the special safety standards imposed by government regulations on nuclear-fueled systems are atypical of photovoltaics; however, the bounds are not rigid. In some cases, practices originally instituted for nuclear power were later adopted in other areas; in other cases, the nuclear practices are considered valuable for photovoltaics.

1.3 RATIONALE FOR STUDYING THE CONVENTIONAL ELECTRIC POWER GENERATING INDUSTRY

The decision to study the conventional electric power generation industry was prompted by three overriding considerations:

- The industry has developed a thorough understanding of the technical, economic, and sociological factors of producing and distributing electric power to public and private users.
- Most PV energy systems will very likely interface with present electric power generating facilities (utilities).
- If photovoltaic energy systems prove economically viable, they will eventually be deployed on a large scale by utilities as an alternative to nonrenewable energy sources.

The conventional electric power generating industry has been successfully serving the electric power needs of industry and consumers for over 75 years. In so doing they have become knowledgeable and have gained broad experience in applying techniques, methods, and practices designed to provide reliable, cost-effective electric power. This experience should be invaluable as a baseline for PV energy systems and components.

Since residential and intermediate load center (ILC) PV systems, in all likelihood, will interface with utilities and, in time, may represent a significant portion of their generating capacity, utilities necessarily will strongly influence the operating, performance, and reliability characteristics of these systems. The use of common terminology and uniform practices will enhance communications and minimize interface difficulties.

Finally, by adopting language and methods that are common to, or understandable by, the electric power generating industry, PV energy systems will be more readily accepted and deployed on a large scale by utilities to augment nonrenewable energy sources.

This study provides a broad understanding of the various approaches, methods, practices, and procedures as well as the terminology used by the different organizations and organizational categories constituting the conventional electric power generating industry. The results will lead to a more intelligent selection and application of QA&R practices best suited for PV energy systems consistent with the nature of the electric power industry.

1.4 STUDY APPROACH

The overall study approach was to:

- Attain detailed data and information through in-depth personal and telephone interviews with representatives from the utilities, AE firms, manufacturers, and others who are active in quality assurance and reliability
- Reduce and analyze all data and information and prepare summary findings and conclusions
- Review summary findings and conclusions with applicable power generating industry representatives to assure accuracy and completeness
- Develop recommendations for PV QA&R programs based on the findings and conclusions.

Table 1-1 lists the information and documentation solicited to assess the scope, depth, organization, procedures, methods, effectiveness, and indices/terminology of the QA&R practices currently being applied and found effective. Organizations that provided information for the study are identified in Table 1-2. Technical discussions were held in depth with the individuals listed in Table 1-3.

1.5 REPORT ORGANIZATION

This report is organized into four sections. Section 2.0 presents a brief description of the electric power generating industry, discusses the electric power availability problem from the standpoint of planned and forced outages and the relationship to equipment/component reliability, and discusses the role of the utilities, AE firms, manufacturers, the various trade associations (i.e., EEI/NERC and EPRI), and DOE in the electric power generating industry. Section 3.0 presents the results of the study. Included are summaries of the information collected and evaluated from the in-depth interviews and telephone calls that were performed during the course of the study. Section 4.0 presents conclusions and recommendations resulting from the study. Specific recommendations for the makeup of a PV reliability program are provided. Definitions and QA&R program elements and practices considered particularly applicable to the PV program are included in Appendices A through D and Appendix E contains an annotated bibliography of the documents collected and reviewed during the study.

Table 1-1. INFORMATION AND DOCUMENTATION REQUESTED FOR STUDY

(1) Management policy statements concerning quality assurance and reliability.

(2) Organization, staffing, authority, and responsibilities of groups responsible for QA&R.

(3) Reliability, maintainability, safety program plans—general and specific.

(4) Reliability indoctrination/training programs for management, engineers, QA&R personnel, QC personnel, manufacturing personnel, operators, and maintenance personnel.

(5) Procedures or description of methods employed in implementing reliability-oriented activities during engineering, testing, production, installation, and operation of systems and components.

(6) Methods and procedures for supplier reliability control.

(7) Documentation of data feedback system in effect within the organization and any employed universally within the industry.

(8) Testing methods and procedures—reliability tests, qualification tests, acceptance tests, etc.

(9) Identification or copies of government and/or other standards and codes that control system reliability and safety.

(10) Technical reports of reliability analysis, testing, operations, research, or other study efforts; reliability data compilations; maintainability data compilations; life-cycle cost analyses and compiled data; availability and outage levels at customer, etc.

(11) Maintainence procedures, maintenance logs and forms, problem areas, etc., relative to system operations and maintenance.

(12) Warranty practices—typical or standardized warranty policy.

(13) Standard or accepted QA&R indices, terms, and definitions.

Table 1-2. ORGANIZATIONS FURNISHING INFORMATION

ARCHITECT-ENGINEER FIRMS

Burns and Roe, Inc., Woodbury, NY
Gibbs & Hill, New York, NY
Gilbert/Commonwealth, PA
GPU Service Corp., Middletown, PA
Kaplan & Associates Inc., Irvine, CA
Pickard, Lowe & Garrick, Inc., Irvine, CA
Power Technologies, Inc., Schenectady, NY
Stearns-Roger Engineering Corp., Denver, CO
Stone & Webster Engineering Corp., Boston, MA

HARDWARE MANUFACTURERS

General Electric, Philadelphia, PA
Hazeltine Corp., Greenlawn, NY
Westinghouse Electric Corp., East Pittsburgh, PA

TECHNICAL CONSULTANT ORGANIZATIONS

American Electric Power Service Corp., New York, NY
Associated Power Analysts, Inc., Bryan, TX
Brown & Root, Inc., Houston, TX
TRW, Inc., McLean, VA
University of Florida, Gainesville, FL
University of Saskatchewan, Canada

TECHNICAL SOCIETIES AND INDUSTRY ASSOCIATIONS

Edison Electric Institute, Washington, DC
Electric Reliability Council of Texas, San Antonio, TX
Electric Power Research Institute, Palo Alto, CA
Institute of Electrical and Electronic Engineers, New York, NY
National Electric Reliability Council, Princeton, NJ

UTILITIES

Investor owned, larger than 5,000 MW (U.S.)

Alabama Power Co., Birmingham, AL
Carolina Power & Light Co., Raleigh, NC
Commonwealth Edison, Chicago, IL
Consolidated Edison, New York, NY
Detroit Edison, Detroit, MI
Florida Power & Light, Miami, FL
Houston Power & Light, Houston, TX
Pacific Gas & Electric Co., San Francisco, CA
Philadelphia Electric Co., Philadelphia, PA

Investor owned, less than 5,000 MW (U.S.)

Consumers Power Co., Jackson, MI
Florida Power Corp., St. Petersburg, FL
Pennsylvania Power & Light Co., Allentown, PA
San Diego Gas & Electric Co., San Diego, CA

Other

Bonneville Power Administration, Portland, OR
Ontario Hydro, Toronto, Ontario, Canada

GOVERNMENT AGENCIES

Department of Energy, Washington, DC
NASA-Lewis Research Center, Cleveland, OH

Table 1-3. INDIVIDUALS AND ORGANIZATIONS INTERVIEWED

J. W. Cowdery, Senior Quality Assurance Engineer, Florida Power & Light
J. E. Vessely, Director of Quality Assurance, Florida Power & Light

A. D. Cooper, Quality Engineering Manager, Westinghouse Electric
T. Soares, Quality Assurance Engineer, Westinghouse Electric
F. S. Maszk, Senior Engineer, Westinghouse Electric
H. S. Darvin, Manager, Source Assurance, Westinghouse Electric

D. Q. Bellinger, Manager, Systems Assurance, TRW

D. Frazier, Manager, Quality Assurance, Houston Power & Light
R. Beauboef, Houston Power & Light

R. H. Iveson, Program Manager, Electric Power Research Institute
W. Lavallee, Nuclear Safety Analysis Center, Electric Power Research Institute
A. Rubio, Director, Nuclear Engineering & Operations Department, Electric Power Research Institute

F. I. Denny, Director of Engineering, Edison Electric Institute

C. Heising, Reliability Consultant, General Electric

D. C. Purdy, Manager, Advanced Technology, Gibbs & Hill

M. F. Chamow, Manager, Power Plant Reliability, Gilbert/Commonwealth
J. A. Flynn, Reliability Engineer, Gilbert/Commonwealth
S. N. Maruvada, Senior Reliability Engineer, Gilbert/Commonwealth

O. S. Gilkes, Senior Examiner, Quality Assurance, Consolidated Edison
E. T. Parascos, Manager, Reliability Engineering, Consolidated Edison
R. C. Rossi, Reliability Engineer, Consolidated Edison

R. J. Squires, Nuclear Reliability, Commonwealth Edison
L. Weyers, Fossil Fuel Reliability, Commonwealth Edison

S. S. Canja, Department of Energy

SECTION 2.0

THE ELECTRIC POWER GENERATING INDUSTRY: AN OVERVIEW

The electric power generating industry is composed of four major interrelated organizational elements:

- Utilities
- Architect-engineer (AE) firms
- Manufacturers and suppliers
- DOE and industrial trade associations (NERC, EPRI).

Figure 2-1 shows the role and relationships of these organizations. The industry's basic objective is to supply safe and reliable electric power to the public at the lowest cost while complying with service commissions and regulatory agencies.

The life of a large power plant exceeds 40 years, and the facility requires operational expenditures of over $150 million/yr (ca. 1978 dollars). Figure 2-2 shows the life cycle and phase durations and expenditures for a typical large power plant. It shows that the majority of life-cycle costs (LCC) is during operation and even though much of the operational cost is fixed, a significant amount varies with operation, maintenance, and fuel control and improvement factors. A forced outage of a major component is costly. The total expense includes not only the cost of repair, which is sizeable, but also the cost of replacement energy and, quite possibly, that of increased reserve generating capacity to offset a higher generating unit outage rate because of the component failure. Thus, Fig. 2-2 indicates that relatively small expenditures during the planning and design phases to improve component reliability (and lower forced outage rates) would substantially reduce expenditures during operation. The electric power industry, recognizing this leverage, directs much effort towards improving component reliability and overall plant performance.

There are over 300 electric utilities in the United States with a peak demand of 100 MW or more. These utilities are investor-owned, municipal, federal, state, and district, or cooperative systems. Figure 2-3 shows the location of the largest (greater than 5,000 MW) electric utilities in the United States in 1977. Because of the extremely large cost of system outages, these organizations generally have the most advanced QA&R engineering programs.

2.1 ELECTRIC POWER SYSTEM DESCRIPTION

A complete electric power system consists of generation, transmission, and distribution subsystems as shown, highly simplified, in Fig. 2-4.

The generator subsystem for fossil fuel plants is composed of a boiler, heaters, a turbine-generator, a condenser, and various power control equipment. The transmission and distribution subsystems consist of cables, transformers, circuit breakers, and transmission lines. This study was limited to assessing the QA&R practices applied to the electric power generation subsystem.

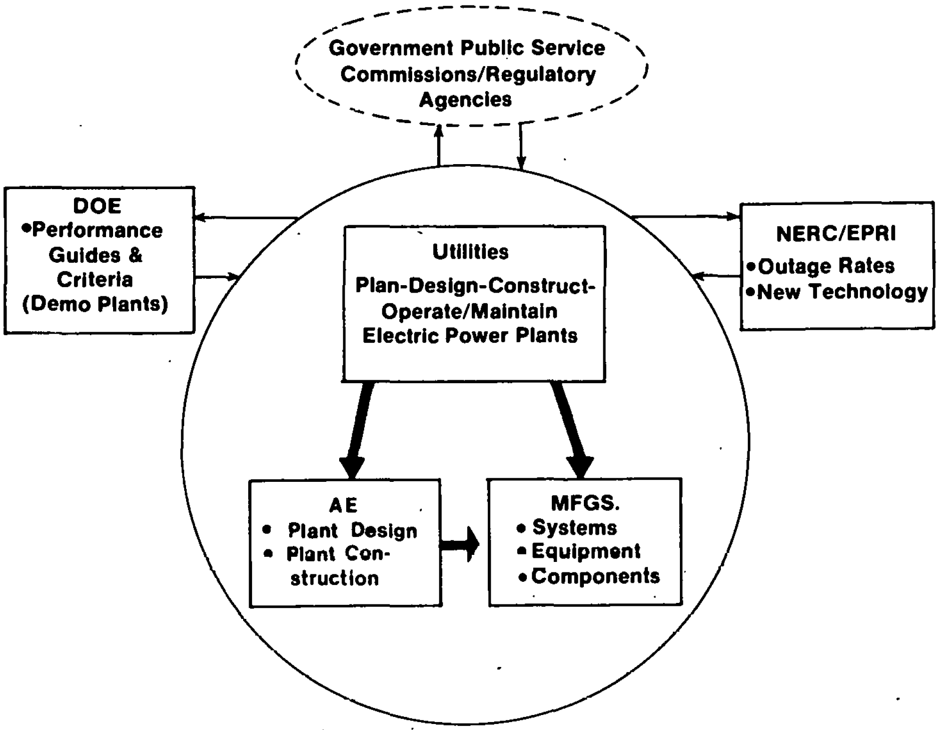


Figure 2-1. Electric Power Generating Industry (Conceptual)

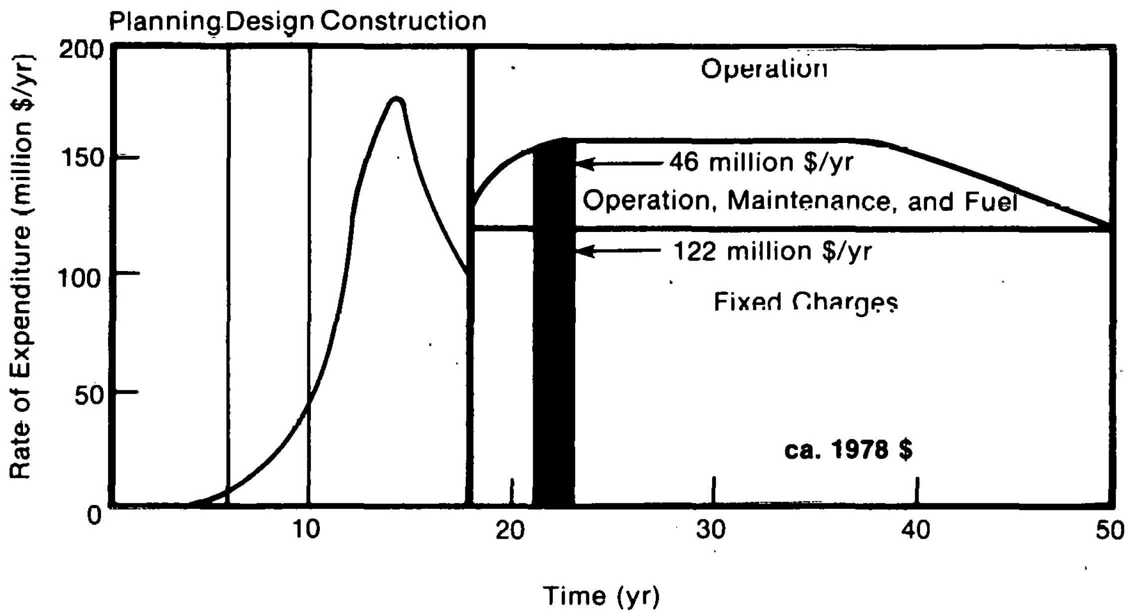


Figure 2-2. Rate of Expenditures vs. Time for a Typical Large Power Plant

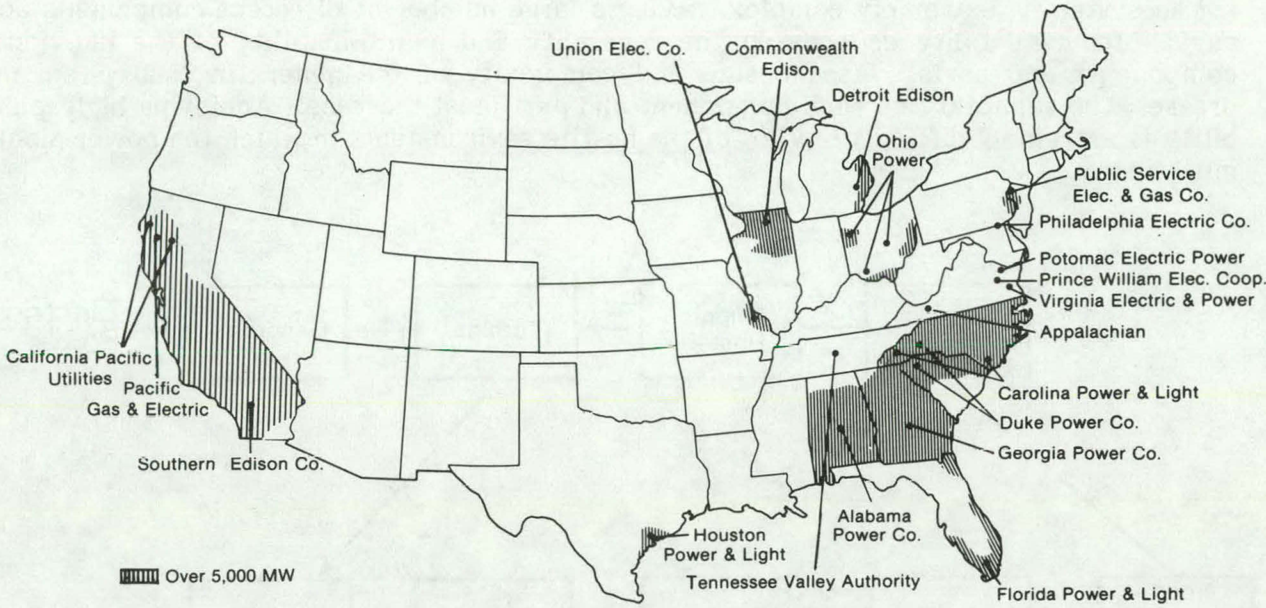


Figure 2-3. Locations of Largest Utilities (>5000 MW)

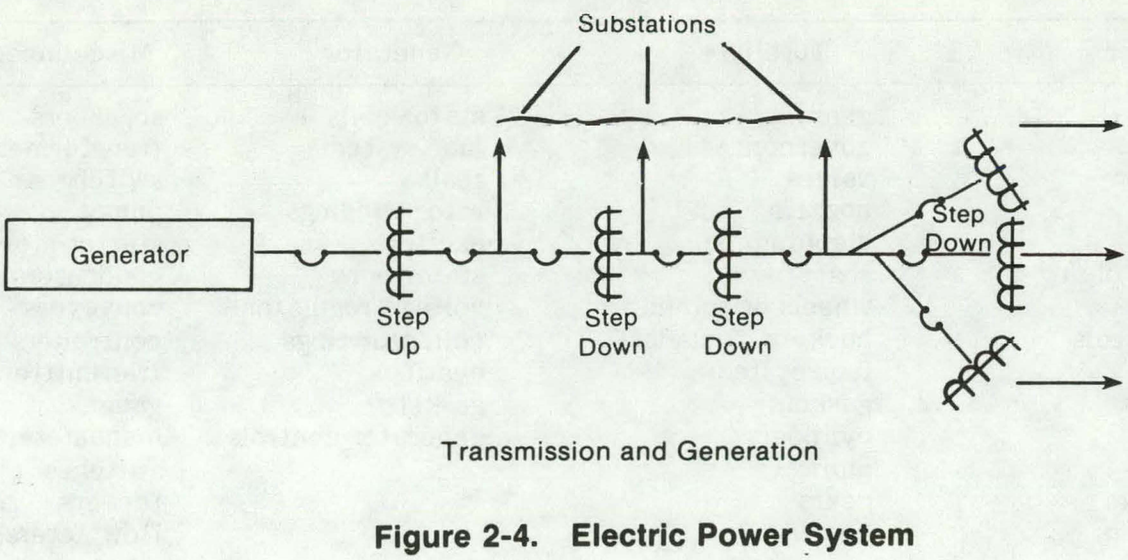


Figure 2-4. Electric Power System

Figure 2-5 presents a generalized schematic of an elementary fossil energy electric power generating subsystem. A partial list of the components and parts that make up this subsystem is given in Table 2-1. As indicated in Fig. 2-5 and Table 2-1, the generating subsystem is extremely complex, having a large number of different components and parts. Its availability depends on the reliability and maintainability of the individual components and parts. As the size and complexity of the generating subsystem increases, the reliability of each component and part must increase. Achieving high reliability is extremely difficult in view of the hostile environments in which the power plants must operate.

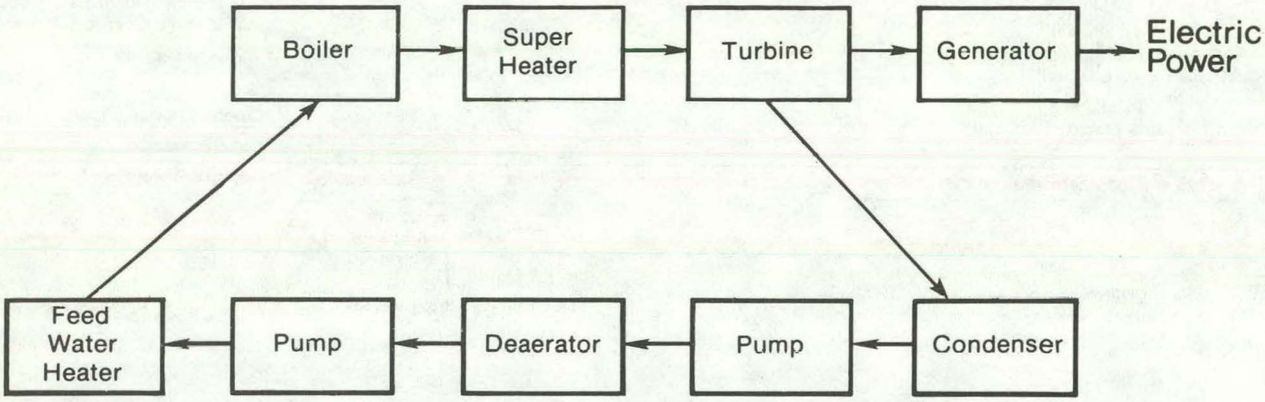


Figure 2-5. Electric Power Generating Subsystem

Table 2-1. ELECTRIC POWER GENERATING COMPONENTS AND PARTS
(Partial List)

Boiler	Turbine	Generator	Miscellaneous
tubes	gears	stator coils	scrubbers
heaters	governors	lube system	transformers
economizer	valves	seals	switchgear
fans	nozzles	rotor windings	pumps
dampers	diaphragms	exciter	starter motors
valves and piping	shaft	stator core	condensers
stack	wheels or spindles	voltage regulator	conveyers
boiler controls	buckets or blades	collector rings	controllers
cyclones	lube system	bearings	transmitters
pulverizers	gaskets	gaskets	gauges
blowers	cylinders	generator controls	manometers
pumps	piping		switches
compressors	gears		feeders
precipitators	bearings		flowmeters
burners	pumps		
	turbine controls		

The physical environments of plant components are characterized by high temperatures and pressures, vibrations, and working fluids and gases that contain corrosive and erosive particulate matter that affects operation. The turbine-generator, for example, is extremely sensitive to the conditions in which it operates. This component has proven to be a major problem in large plants causing high repair costs and extended outage periods. The turbine blade is subject to solid particle erosion, water induction, and stress-corrosion fatigue. The generator is also subject to erosive and corrosive failures. Although bearing failures, which are a leading cause of turbine-generator forced outages, generally are attributed to inadequate design and lubrication systems, their failure mechanisms are accelerated by plant operating and environmental stresses.

2.2 SYSTEM AVAILABILITY

The availability of electric power to meet load demands is a prime consideration in evaluating power generating systems. Availability engineering concepts and techniques are applied to assess the performance of major components, to aid in the modification of operating systems, and to help design new systems. Past experience, expressed as outage frequency and duration, is used to identify availability-related deficiencies in hardware, software, and personnel actions as well as to assess system availability. Corrective actions that can achieve an availability goal, while considering potential savings and costs, are identified through availability analyses. Controls that must be imposed to prevent degradation during installation and operation and maintenance are also identified through availability analyses. Availability engineering involves performing systematic and highly disciplined efforts to set and achieve a quantitative availability goal at minimum cost.

2.2.1 Availability Indices (or Measures)

Availability, usually expressed as a percentage, is a figure that reflects the ability of an item to meet its intended duty cycle. It is the percentage of time that an item is neither forced nor scheduled out of service. Formulas used to analyze availability include:

$$\text{Operating Availability} = (\text{AH}/\text{PH}) \times 100$$

$$\text{Equivalent Availability} = \frac{\text{AH} - (\text{EFOH} + \text{ESOH})}{\text{PH}} \times 100$$

where

$$\text{EFOH (equivalent forced outage hours)} = \frac{\text{FPOH} \times (\text{size of reduction})}{\text{rated capacity}} ,$$

and

$$\text{ESOH (equivalent scheduled outage hours)} = \frac{\text{SPOH x (size of reduction)}}{\text{rated capacity}} ,$$

$$\text{Capacity Factor} = \frac{\text{Total generation in MW/h}}{\text{PH x MDC}} \times 100 ,$$

$$\text{Forced Outage Rate} = \frac{\text{FOH}}{\text{SH + FOH}} \times 100 .$$

Availability parameters are defined as follows:

Available Hours (AH)	=	The time in hours during which a unit or major equipment is available.
Forced Outage Hours (FOH)	=	The time in hours during which a unit or major equipment was unavailable due to a forced outage
Forced Partial Outage Hours (FPOH)	=	The time in hours during which a unit or major unit or major piece of equipment is unavailable for full load due to a forced partial outage.
Maintenance Outage Hours (MOH)	=	The time in hours during which a unit or major piece of equipment is unavailable due to a maintenance outage.
Period Hours (PH)	=	The clock hours in the period under consideration.
Planned Outage Hours (POH)	=	The time in hours during which a unit or major piece of equipment is unavailable due to a planned outage.
Reserve Shutdown Hours (RSH)	=	Reserve shutdown duration in hours
Maximum Dependable Capacity (MDC)	=	The dependable main-unit capacity in winter, or summer, whichever is smaller.

Scheduled Partial Outage in Hours (SPOH)	=	The time in hours during which a unit or major piece of equipment is unavailable for full load due to a scheduled partial outage.
Service Hours (SH)	=	The total number of hours the unit was actually operated with breakers closed to the station bus.

These equations and parameters have been defined and used by NERC/EEI in their availability data reporting system.

Analyses are performed, in general, by the utilities to estimate values for system/component availability (operating and equivalent) and capacity factor. The operating and outage experience found in the utilities' internal data banks and/or NERC's availability data reporting system are used as input to the analyses. These analyses account for frequency, duration, and effect on output power of the major outages and the various modes of operation. An availability model is developed as part of the analysis that allows combining the various outage rates and other parameters associated with each of the subsystems and components that constitute a power generating unit.

Many utilities also use a loss of load probability (LOLP) criterion in analyzing power plant availability. LOLP represents the expected number of days for a given time period during which system load may exceed available generating capacity within the system. LOLP accounts for installed capability relative to peak annual load and is especially useful for power plant planning and component design trade-off studies because it is sensitive to the sizes and outage rates of the individual generating units, the annual load profile, maintenance scheduling, and load forecast derivations. A one-day loss of load in ten years is the generally accepted industry standard.

2.2.2 System and Component Outages

The availability of a power generating system is a direct result of both planned and forced outages. The result is that the total power required at any particular time may not be available and must be produced by other, perhaps less economical, units in the plant or purchased at higher cost from neighboring systems.

2.2.2.1 Planned Outages

Planned outages include normal maintenance, inspections, and equipment overhauls at specified time intervals. Typically, planned maintenance (PM) procedures and schedules are recommended by the manufacturer and followed at the discretion of the utility depending on their own experience and judgment to guide PM priorities. These planned outages generally follow a pattern of increasing complexity, depending on the operating times accumulated by the unit. For example, four principal areas of inspection for a gas turbine unit include:

- Service Inspection—General operating condition is inspected including automatic controls, gas turbines, and associated equipment. Usually performed monthly.
- Combustion Inspection—Includes entire combustion chamber and some portions of the hot gas path. Usually performed quarterly.
- Hot Gas Path Inspection—May require removing turbine cover for detailed inspection of turbine blading. Stops short of pulling the turbine rotor.
- Major Inspection—Includes all of the above aspects of maintenance with the removal of the turbine rotor and complete bearing inspection.

The time required to complete each ranges from several hours for a combustion inspection to several weeks for a full turbine overhaul.

2.2.2.2 Forced Outage Rates

Forced outages occur when equipment malfunctions interrupt equipment usage during normal operating periods. Forced outages include such things as emergency tripouts, unscheduled shutdowns, and failure to start. Each piece of equipment or component in an electric generating unit has an associated historical forced outage rate (FOR) that contributes to total unavailability. Most large utilities implement a computerized data collection and recovery system to provide historical FORs that reflect their specific operating experience and environmental characteristics. In addition, NERC collects and publishes industry-wide generic FOR data (see Sec. 3.4). As previously indicated, historical FORs and duration times are essential in computing and evaluating electric power generating availability. FOR data provides the utilities with a basis for assigning priorities, conducting life-cycle cost/benefit studies, and implementing product/component programs. Although FORs for power generating systems and components vary widely with plant location and operational factors, the NERC data shows that across the industry, the turbine-generator and boiler account for about 90% of the forced outage hours and all other components constitute the remaining 10%. This accounts for the priority given by the utilities, manufacturers, and EPRI to improve the reliability of the turbine-generator and boiler.

Electric-power generating units and components generally exhibit an increasing failure (or forced outage) rate as they age, in contrast to electronic components, which exhibit constant failure rates. Thus, with power generating units and components, it is beneficial to inspect (using NDT techniques) for indications of failure as part of the overall maintenance program. The intent is to reduce the frequency of forced outages and the need for corrective maintenance by replacing components whose performance and physical attributes are beyond predetermined acceptance levels (derived from failure rate studies) and would fail during use. A trade-off exists between preventive and corrective maintenance, and cost/benefit analyses can be and frequently are performed to determine the optimum maintenance program.

2.2.3 Availability Improvement Approaches

Availability requirements or goals are met by reducing the frequency and duration of outages. Table 2-2 lists some of the general design techniques that are considered in reducing outages.

Table 2-2. RELIABILITY AND MAINTAINABILITY IMPROVEMENT ATTRIBUTES

Reliability (reduces outage frequency)
1. Select parts, components and equipment of proven reliability and durability.
2. Derate parts and components.
3. Use carefully designed-in redundancy where feasible and cost-effective.
4. Apply well planned and documented reliability testing, including reliability growth, demonstration, and acceptance.
5. Apply effective reliability controls, disciplines, and provisions during equipment/component development.
6. Specify adequate and consistent quality controls to ensure that the inherent reliability is maintained during construction.
7. Perform ongoing monitoring of supplier activities to ensure adherence to reliability and quality requirements.
8. Analyze failures with rapid feedback for correction.
9. Redesign to simplify equipment and eliminate areas of unreliability.

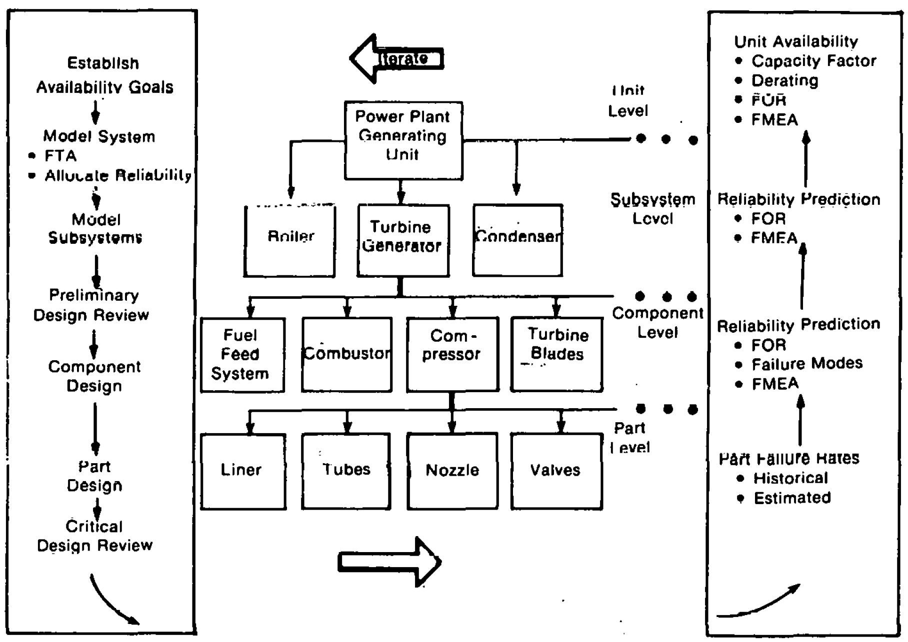
Maintainability (reduces outage duration)
1. Design to incorporate easily accessible and interchangeable components, modules, assemblies, and equipment.
2. Provide automatic detection, location, and diagnostic features to the maximum extent possible.
3. Provide features to increase ease of maintenance such as work platforms, hoists, proper tools, etc.
4. Provide automatic scanning of selected measures of performance.
5. Define areas for preventive maintenance based on failure trend data.
6. Determine maintenance load based on trend diagnostics and field outage data.
7. Apply effective maintainability engineering analysis, controls, and provisions during equipment/component development.
8. Perform carefully planned and documented maintainability tests.
9. Specify an effective maintenance environment in terms of lighting, temperature and humidity control, odor and sound control, and cleanliness.
10. Prepare accurate, easy to read, and concise maintenance procedures.

Electric power plant equipment and components may fall into one of two categories:

- Large, expensive, hard-to-replace items, such as boilers, turbine-generators, and condensers, that are customized to meet the requirements of the individual utility and where much of the final fabrication is accomplished on-site during plant construction
- Small, numerous items, such as transformers, overload protectors, terminations, cabling, valves, and various electronic control equipment, that are somewhat standard and common to many power plants.

The category into which an item falls usually dictates how availability is controlled and improved and how the frequency and duration of outages are reduced.

R&M engineering analysis and methods are used to predict the frequency of failure (reliability) and the duration of the failures (maintainability) and to identify areas where design improvements can be made most cost-effectively. Many analysis methods are available; they differ in the level of part and component attribute data required for their application. Figure 2-6 depicts some of these procedures and illustrates when they are applied during the development of a power plant generating unit to meet (or improve) availability goals. The figure shows that as the development program progresses, reliability allocation, prediction, and availability analysis, as part of an overall iterated process, are continually updated to reflect the more detailed level of hardware definition. Reliability techniques appropriate to each level of design and some of the data necessary to support the application of the particular technique are indicated.



FTA: Fault Tree Analysis
FOR: Forced Outage Rate
FMEA: Failure Mode and Effects Analysis

Figure 2-6. Reliability/Availability Methodology

SECTION 3.0

RESULTS OF THE STUDY

The QA&R efforts practiced by the electric power generating industry are driven by the need to reduce costs. Efforts focus on increasing productivity by reducing plant downtime and offsetting rising costs. The QA&R programs generally include minimum standards of quality and reliability in the purchase, construction, and operation and maintenance of the facilities.

QA&R responsibilities and activities are broad, covering a wide range, but for analysis purposes may be considered to fall within the major areas shown in Table 3-1. This chart was developed from information collected from organizations (particularly utility companies) contacted during the study that were active in quality assurance and reliability.

Table 3-1. QUALITY ASSURANCE AND RELIABILITY PROGRAM ACTIVITIES

Manufacturing Audit and Surveillance: On-going audits and surveillances that ensure the adequacy of QA programs

Standards, Specifications, and Guidelines: formal documents that aid in procuring new (or replacement) units or components

Life-Cycle Cost Benefit Analysis: Support costs as well as initial costs considered in evaluating the effectiveness of an item, process, or requirement

Reliability Indoctrination and Training: Formal training in the application of basic QA&R tasks

Availability Assessment and Analysis: Analytical methods that evaluate availability based on system modeling (R&M, LOLP, capacity factors, etc.) using historical data forced/planned outage rates

Quality Engineering: Organized efforts that assure that manufactured equipment, components, and materials are in compliance with specified requirements

Reliability Engineering: Support designed by performing systematic and timely management and engineering activities (prediction, FMEA, design review, etc.) to ensure reliability

Failure Analysis: The determination of root causes of operational failures for feedback to design for corrective action

Data Recovery and Feedback (internal): O&M data collected for feedback to management and design

All organizations contacted implement efforts that ensure the quality and reliability of the power generating units and equipment. The formality, scope, and rigor of the program vary greatly with each organization and its functional responsibility. In general, the industry (as shown in Table 3-1) emphasizes problem resolution. It performs audits and quality engineering activities and analyzes and corrects operational failures and maintenance problems as they arise. The more advanced organizations, in terms of reliability, are adopting a preventive approach and are implementing a full and comprehensive QA&R program that includes developing standards, specifications, and guidelines; performing availability assessments, reliability predictions, design review, Failure Mode and Effect Analysis (FMEA), and Fault Tree Analysis (FTA); conducting formal reliability training; auditing and surveying supplier programs; analyzing failed components; and conducting quality engineering activities. Some of the reliability activities have been initiated on a formal basis only within the past two to three years. Many organizations operate an internal, dedicated reliability data recovery and feedback system as well as participating in NERC's industry-wide generic data collection and feedback system. Most of the organizations contacted maintain a formal quality assurance (or quality engineering) function; approximately half also maintain a separate reliability organization, while a fairly small percentage maintains a combined reliability and quality function. Staff sizes range from a few to over 200, with the majority assigned to quality assurance activities.

Sections 3.1 through 3.5 characterize the QA&R efforts practiced by utilities, architectural engineering firms, manufacturers, electric power industry trade associations, and DOE, based on information attained from interviews, telephone calls, and mailings conducted during the course of this study. Brief descriptions of techniques considered particularly applicable to the PV reliability program are presented.

3.1 UTILITY QA&R PRACTICES

Audits and surveillances of manufacturer's QA&R programs are performed by most utilities. Many utilities consider this the most effective activity for identifying and correcting problems prior to product acceptance. Various techniques have been developed and implemented for performing manufacturing audits and surveillances. For example, the Bonneville Power Administration (BPA) has developed a detailed quality assurance report that they use to survey their contractors. This report provides for a complete evaluation of a contractor's ability to perform. It provides criteria for determining the adequacy of quality assurance elements including receiving inspection, fabrication control, process control, drawing control, inspection and test procedures, nonconforming material records, information feedback, etc., and leads to a complete contractor evaluation profile. The report provides preaward surveys as well as follow-up factory surveillance. BPA's report form and specifications covering its overall quality program requirements are given in Appendix C.

Standards and guidelines used as aids in determining consistent and cost-effective QA&R specifications for procuring generating units and components (new or replacement) are prepared as a formal activity by approximately half the utilities sampled. Procurement specifications generally include QA requirements, controls, and provisions. Although a few of the utilities specify reliability requirements and control provisions, quantitative reliability requirements are normally not (or not extensively) included in procurement specifications. Many utilities have developed quality standards for contractors that they incorporate into their procurement specifications (e.g., BPA—see Appendix C).

Consolidated Edison has developed specific QA requirements for their manufacturers based on Military Specification MIL-Q-9858.* A matrix (see Appendix D) is used to delineate four separate levels of quality assurance effort required of their supplier. These levels of effort are specified as: Levels A, B, C, and D. Level A, the highest level of effort required, is normally used for those components requiring a special quality assurance plan covering design, manufacturing, and inspection quality control. Level D, the lowest level, covers the great majority of standard, noncomplex articles where in-process and end-product inspections provide adequate assurance of quality. In this case, inspection control alone is specified. Levels B and C are intended for intermediate levels of QA effort. Level E, a fifth level which is not covered by a specification, is intended for equipment and supplies that do not require a formal quality assurance effort. Specific definitions for each of the levels are given in Table 3-2.

Ontario Hydro has developed a similiar matrix for structuring reliability programs. The equipment is classified in terms of criticality, maturity of design, operational experience, and experience with the manufacturer; the level of reliability programs are applied accordingly (see Table 3-3). They also include a reliability (and maintainability) clause in their technical specifications (Walters 1979). The clause reflects the reliability level that matches the equipment class, criticality, and experience factors, and it provides specific quantitative and qualitative reliability requirements and program documentation and acceptance requirements (see Table 3-3). A description of these requirements is given in Table 3-4.

Life-cycle cost (LCC) benefit analyses are performed by several utilities to compare competing designs or perform design trade-offs for new procurements or to evaluate the effect of changes to existing systems or components. BPA, for example, is applying LCC analysis for overall cost-effectiveness to determine the extent and level of reliability to specify during procurement (Vanderzanden 1980). This concept (see Fig. 3-1) allows early quantitative trade-off analyses between initial acquisition cost and recurring support cost to determine the desired degree of performance reliability (and maintainability). The intent is to determine the value of reliability that would minimize total LCC and then incorporate that value directly (or indirectly through required qualitative design features or attributes) into the hardware procurement specification or possibly to use as the basis for establishing a warranty agreement.

Figure 3-2 illustrates (conceptually) the LCC trade-off concept. The figure shows that as equipment is made more reliable (all other factors held constant), the support cost will decrease since there are fewer failures. At the same time, initial cost must be increased to attain the improved reliability. At a given point, the amount of money spent on increasing reliability will result in exactly that same amount saved in support cost. This point represents the reliability for which total cost is minimal. Consequently, reliability can be viewed as an investment for which the return is a substantial reduction of support cost.

Figure 3-2 also shows that a reliability improvement profit incentive exists if a warranty is incorporated into the contract where the manufacturer provides repair and replacement of failed equipment for a specified period at a fixed price.

*MIL-Q-9858, "Quality Program Requirements," is the basic standard for planning quality programs for Department of Defense development and production contracts. It outlines provisions to ensure appropriate levels of quality over the development and production cycle through effective management action.

Table 3-2. QUALITY CONTROL LEVEL DEFINITIONS

Level A

A piece of machinery, equipment, structure, or part thereof whose design is such that a significant extension of the state of the art will be necessary to produce the item. Such items will require extensive design work and a special quality assurance effort. Therefore, Level A requires quality assurance controls in the design area as well as manufacturing, procurement, and inspection control. A specifically tailored quality assurance plan is also required to ensure that adequate quality control measures are utilized in areas where a state-of-the-art extension is needed to develop and manufacture the equipment. An example of the type of equipment requiring Level A quality assurance effort is a generator having a rating significantly larger than generators previously built or a turbine whose final stage blade height is larger than previously provided for utility power generation applications.

Level B

A piece of machinery, equipment, structure, or part thereof whose design is such that a significant design effort will be necessary to produce the item. Therefore, control of design activities is required along with procurement, manufacturing, and inspection control. The plant-wide quality assurance program is specified in this case since the equipment would be similar to equipment previously produced by the seller and a tailor-made plan would not be required. An example of the type of equipment requiring Level B quality assurance effort is a substation transformer where the size, rating, or physical restrictions require extensive design.

Level C

A piece of machinery, equipment, structure, or part thereof that is the seller's standard product and is of sufficient complexity to merit quality control of manufacturing procurement and inspection functions using the seller's plant-wide quality assurance program. An example of the type of equipment requiring Level C quality assurance effort is a standard design boiler feed pump.

Level D

A piece of machinery, equipment, structure, or part thereof that is the seller's standard product and is simple in nature and can be inspected and tested during and at the completion of manufacture. Therefore, Level D requires inspection control only in accordance with the seller's standard inspection plan. An example of the type of equipment requiring Level D quality assurance effort is the transmission line insulator where final testing can verify acceptable quality.

Level E

Equipment and supplies that do not warrant a formal quality assurance effort.

Source: Consolidated Edison (1972).

Table 3-3. ONTARIO HYDRO RELIABILITY PROGRAM MATRIX

Program Description	Equipment Class* 1	2	3
1.0 Program management			
1.1 Organization	A	A	C
1.2 R&M program plan	A	B	C
1.3 R&M program review	A	B	C
1.4 Reliability training	A	B	C
2.0 Program elements			
2.1 General	A	B	C
2.2 Design description, specification and requirements	A	A	B
2.3 Data collection—field experience feedback	A	A	B
2.4 Reliability analysis	A	B	C
2.5 Reliability prediction	A	B	C
2.6 Maintainability			
2.6.1 Maintainability design	A	B	C
2.6.2 Maintenance monitoring	A	B	C
2.6.3 Maintenance strategy Including role of service, organization, spare parts provisioning and manuals	A	A	A
2.7 Human errors	A	B	C
2.8 Design reviews	A	B	B
2.9 Standardization of design practice	A	B	C
2.10 Decisions	A	B	C
3.0 Testing			
3.1 Test program and purpose	A	B	B
3.2 Measurement	A	B	C
3.3 Data	A	B	C
4.0 Program evaluation			
4.1 Initial evaluation	A	B	C
4.2 Continual evaluation	A	B	C

*Equipment Class
1 - Major
2 - Rotating
3 - Stationary

Depth of R&M Activities
Level A. Extensive application, well developed separate function
B. Application done selectively on areas identified as weak or critical
C. More limited and selective than level B

Source: R. J. Walters (1979).

Table 3-4. ONTARIO HYDRO RELIABILITY AND MAINTAINABILITY SPECIFICATION REQUIREMENTS

1. Quantitative and qualitative R&M requirements. These include quantitative requirements for Availability A, starting Reliability R_s, and running reliability R_r.

   Qualitative requirements for those features that are definite requirements.

2. R&M program requirements. The essential elements of an R&M program are:

   - Corrective action program
   - Failure analysis and predictions
   - Maintenance and maintainability analysis
   - Design reviews
   - R&M test programs
   - Standardization
   - Spare parts program and service organization
   - Subcontractor program and control

   The elements required in the program depend on the maturity of the equipment design, operational experience with the equipment, and familiarity of the designer with the supplier and equipment. Less maturity, less operational experience, and less familiarity of the designer with the equipment, will necessitate a more extensive program.

3. Data/document required. Information required of the (prospective) supplier before and after the award of contract should be specified herein. Typically, the following information should be submitted with the tender: relevant operational experience; description of supplier's R&M program; prediction of parameters such as A, R_s, and R_r, for the tendered equipment; recommended preventive maintenance schedule; recommended spare parts; and a description of the supplier's service organization and its capabilities.

   Information that the supplier is to supply after the award of contract should include the following: R&M program schedule, showing key milestones like design reviews, failure analysis, reliability tests, etc.; documentation of failure analysis and prediction; design review input and output packages; recommended maintenance schedule; spare parts list; test plans; test results; and operation and maintenance (O&M) manual that includes a trouble-shooting guide, etc.

4. Acceptance test requirement. Requirements for test to demonstrate R&M performance such as starting reliability and running reliability should be specified.

Source: T. J. Ravishankar (1980). See Bibliography.

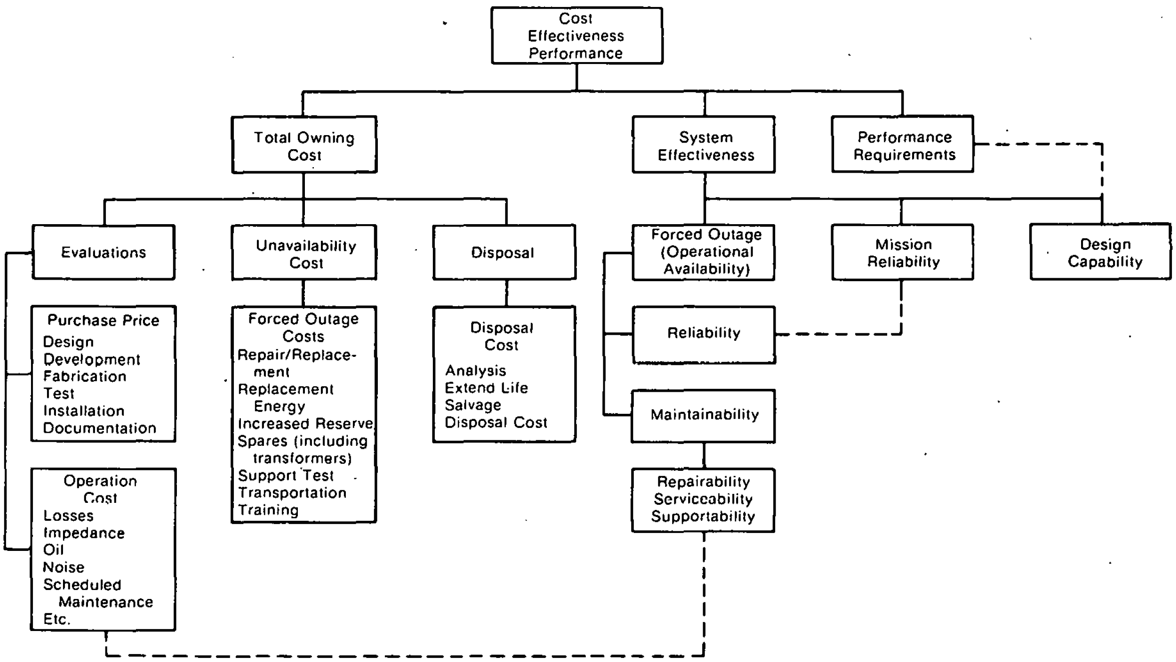


Figure 3-1. System Cost-Effectiveness-Performance Concept

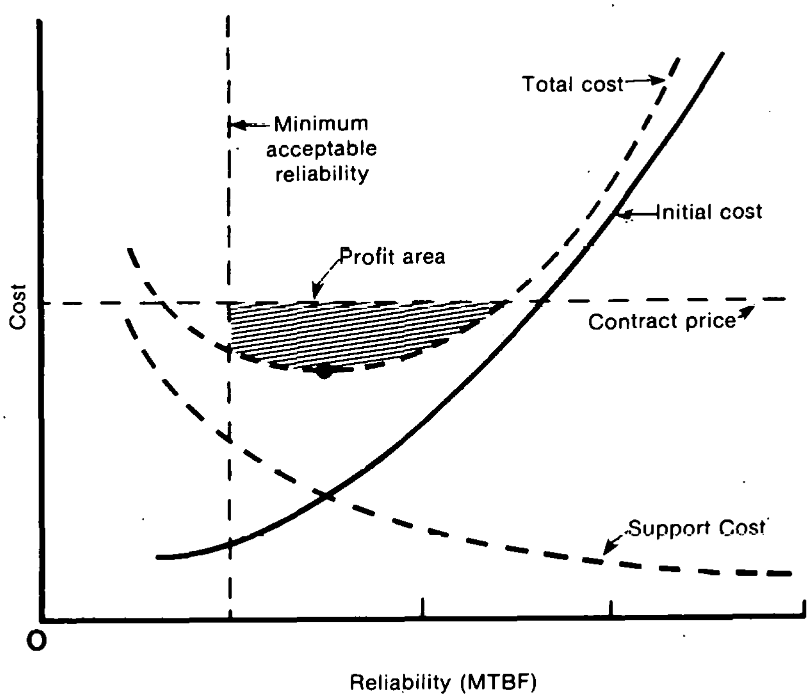


Figure 3-2. Effect of Reliability on Initial and Support Costs FPL Power Generating Reliability Input-Output Model

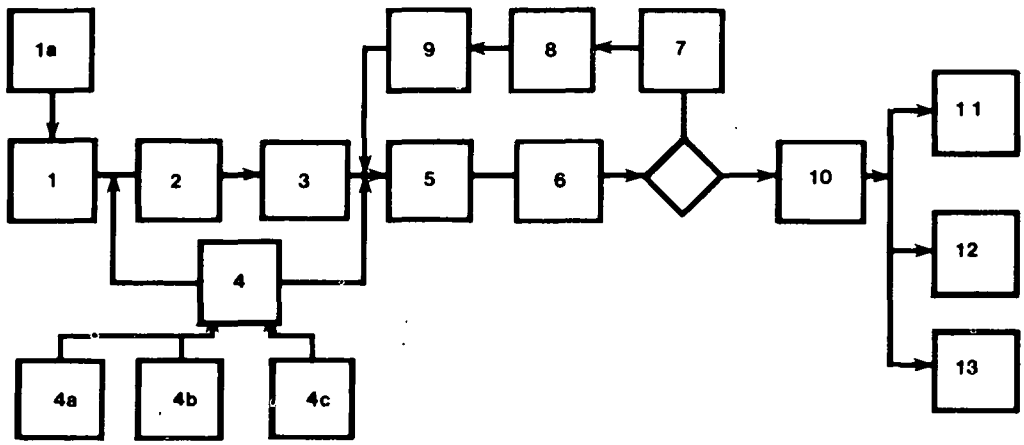
Although the utilities generally conduct O&M training programs, only a few of the utilities contacted currently conduct formal indoctrination and training in the application of basic reliability and quality assurance tasks. Consolidated Edison is one of the utilities that stresses reliability training. They have developed a comprehensive reliability, availability, and maintainability (RAM) engineering training program. The program covers the fundamentals of RAM including definition of terms, reliability statistics, system effectiveness, design review, specification, LCC analysis, FTA, failure mode and effect analysis, and failure analysis. Training material, including three volumes of text material, reference papers, definitions, illustrations, and examples, has been prepared and is used for the training course. The course is conducted on a regular basis and is given to engineers, QA&R personnel, O&M personnel, management, and others who are active or are interested in reliability.

It should be noted that organizations that conduct QA&R training also appear to adopt a more preventive approach to assuring reliability and, consequently, these organizations also perform activities such as reliability prediction, FMEA, and LCC benefit analysis, as well as incorporating reliability requirements into their basic procurement specifications.

The availability of electric power to meet load demands is continually assessed and analyzed by most utilities. Availability analyses are based on system outage rates (forced and planned) compiled by the utilities and supplemented with industry-wide data from NERC. These assessments provide an effective and viable basis to correct and improve the plant/system. Other analyses performed by many utilities during the design and development of new systems/components assess availability based on system reliability prior to actual plant operation. These analyses use generic historical data at the component level derived from the utilities internal and/or NERC data collection systems. They assess reliability (at start-up as well as when running) and identify problems during development when corrective changes can be implemented most cost-effectively. These predictive efforts provide inputs for budgeting program activities, developing LCC estimates, and performing LCC benefit studies. Standard reliability prediction techniques and other reliability analyses, including FMEA, FTA, and design review adapted from aerospace programs, are performed during system planning and design and during plant construction to ensure reliability. Florida Power and Light (FP&L), for example, has developed an overall reliability method (called an input-output model) that incorporates prediction, FMEA/FTA, and other techniques that are applied to new power generating equipment (Zagursky and Pillar 1980). Application of this procedure starts at early design planning and ends with the preparation of operation and maintenance procedures. Figure 3-3 shows the model and describes the activities.

Several utilities have established formal failure analysis programs to determine the root cause of failure. In general, the analysis is supplementary to that performed by the manufacturers. Manufacturers generally provide an analysis of equipment that was repaired and replaced. Utilities, many times working with the manufacturers and outside failure analysis labs, perform detailed analysis that leads to improved equipment or component design based on failure trends.

Failure analysis is initiated by identifying trends, patterns, or problem areas through continuous assessment and evaluation of equipment/component reliability performance. As indicated in Table 3-1, most utilities have internal data recovery and feedback systems. The objectives of these systems are to continually assess the availability of the generating units and their major equipment and components and, as previously indicated, to provide information concerning failures, performance degradation, trends, patterns, or potential problems so corrective action can be initiated. EEI/NERC definitions are



1. Determine Availability Requirements (Goals) — Base on economics and consideration of actual availability achieved under similar conditions.

1a. Monitor External Forces — Regulatory requirements may dictate plant availability goals.

2. Prepare Allocation Model — Construct model consistent with data available and design stage.

3. Allocate Goals — Allocate system goal to sub-elements.

4. Process Data — Data used as predictive input in subsequent analyses.

4a. Industry Data — Compiled from various sources such as NERC/EEI, NPRDS, and Institute of Electrical and Electronic Engineers.

4b. Vendor Data — Used preferentially when they can be verified.

4c. Plant Data — Information on Product performance in the O&M environment.

5. System Failure Analysis (FMEA/FTA) — Identify the effects of possible failures, faults, or mistakes.

6. System Reliability Assessment — Combine the allocation model and system failure analysis to provide a means for predicting R.

7. Identify Problem Areas (critical items list) — Base on failure analyses and numerical predictions.

8. Conduct Critical Item Reviews — Review periodically.

9. Develop Corrective Action — Develop Corrective action plan based on information derived during the critical item reviews.

10. Implement Corrective Action — Increase availability by changing one or more of the following:
    - Hardware
        - Component/system service equipment reliability
        - Maintainability/accessibility
        - Spares/redundancy
    - Software
        - Installation/start-up/test procedures
        - Maintenance schedules
        - Repair and overhaul procedures
        - Inspection intervals and instructions
    - Personnel
        - Skill levels and training
        - Motivation

11. Reliable System Design — Changes in design configuration components must be fully documented.

12. Reliability Requirements in Procurement Specifications — Write to ensure that procured equipment can meet its availability goal in terms of its R&M ability characteristics. Wherever possible, quantitative requirements should be specified.

13. Improved O&M Procedures — Operator error can defeat the best intentions in engineering design.

Figure 3-3. Florida Power & Light Power Generating Reliability Input-Output Model

generally used for data reporting and feedback. The basic failure data is reported from each plant via failure reports completed by the plant operator.

FP&L, for example, is implementing a comprehensive data collection and feedback system called Generation Equipment Management System (GEMS) (Vessely and Cowdrey 1980). GEMS translates a plant work order into various computer codes that provide information as to plant unit, specific equipment involved, major and minor equipment codes, action taken, manufacturers, reason/root cause codes, outage hours, power curtailed (in MW), man-hours spent in repair, materials and their costs, and contractor cost. These data have provided an essential starting point for improvement efforts. GEMS was established in 1971 and tied to work orders in 1972. This system currently has over 350,000 records in its data base and routinely issues over 1,200 reports annually on request plus hundreds of routine reports.

Failure (or defect) reports have been designed to reflect the characteristics and potential failure modes of the major equipment and components used in the generating units. Consolidated Edison has developed individual and highly detailed forms for each of the major components and pieces of equipment that make up an electric power generating system; others have developed generic forms common to all equipment and components.

Various methods are used to report data. Figure 3-4 shows the form used by FP&L in reporting unit availability. Data analysis reports, such as FP&L's, provide information that can be used for designing new units and equipment as well as establishing priorities for reliability failure analysis projects, which identify root causes and establish corrective or improvement programs. Many times only a few components or problem areas account for most of a system's unavailability. Data collection and feedback identify these critical components and problem areas.

3.2 ARCHITECT-ENGINEER FIRM QA&R PRACTICES

The architect-engineer (AE) firms address QA&R as an integral part of the plant design, development, and facility construction process. QA&R efforts include establishing minimum requirements for quality and reliability in the engineering design documentation and construction operations.

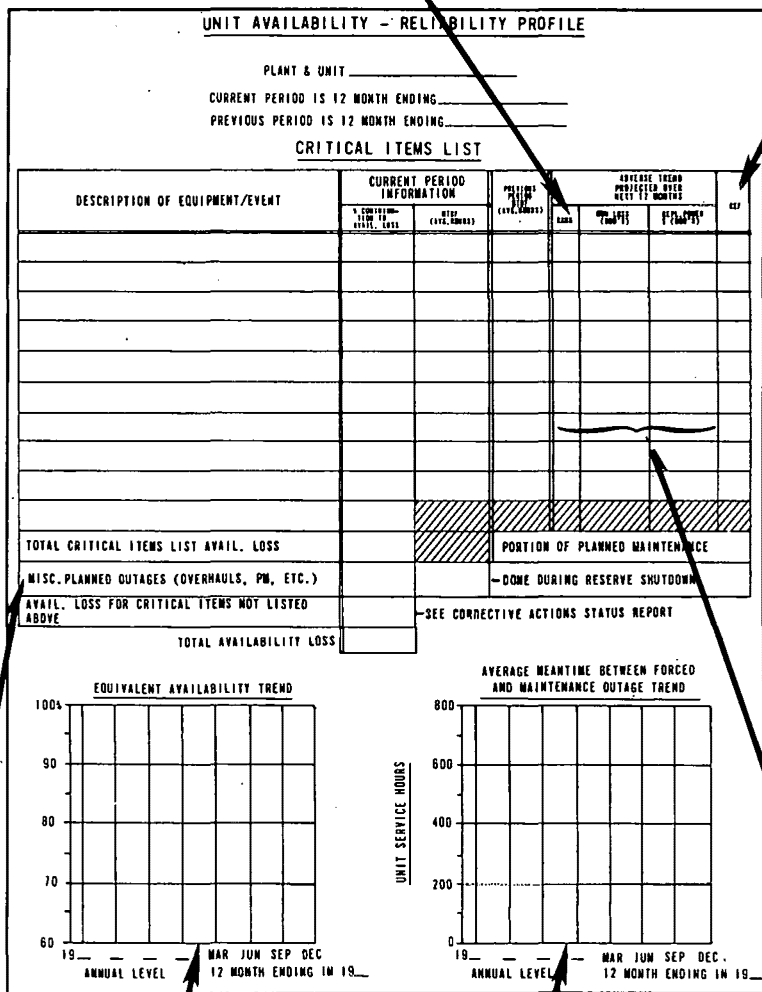
AE firms generally implement efforts to ensure that power plants and the generating units and components are designed, developed, and constructed to meet the minimum standards for quality and reliability. The formality, scope, and rigor of the programs vary widely. Some firms develop a full and comprehensive program that includes manufacturer auditing and surveillance, training, availability analysis and LCC-benefit studies, failure analyses, and data recording and feedback. Others concentrate on availability analyses, risk analysis, and cost trade-off studies. Most firms contacted emphasize the selection and specification of quality material and components and the application of controls and high quality workmanship during fabrication and construction. However, they are increasingly concerned about reliability engineering and controls, particularly in determining and incorporating cost-effective quantitative requirements into plant design and specification documents. Those firms that stress reliability perform detailed reliability, availability, and LCC trade-off studies to determine optimum design requirements. The trade-offs include:

- Reliability level versus LCC (initial cost versus support cost)

These items are ranked in order of the highest contributor to the unit's availability loss for the current period.

This ranks the items according to their projected economic impact on the unit.

This number corresponds to the number shown in the REF. column of a specific plant's Corrective Action Status Report.



Planned events/work are accounted for on this line. While these may be the major contributors to availability loss for the period, this report is intended to highlight trouble items which cause generation losses.

This graph shows the ratio of the total MWh available to the total MWh in the period. It does NOT give credit for outages that were worked under reserve shutdown outages; it does give credit for work requiring an outage that is done under other outages in the same time frame.

This graph indicates the reliability of the unit by showing the average number of hours that the unit operated between outages affecting unit capability (partial outages are included.)

The adverse trend projection is calculated only for those items whose failure rate has not improved by 10% or more from the previous period. The failure rate of the current period is divided into the projected running time for the next 12 months (from System Planning) to give the expected number of failures. This is multiplied by the mean time to repair (for those failures) to give the projected MWh lost. These are multiplied by the cost of replacement power to show the projected economic impact of the event. This is intended to show the minimum expected economic impact of the event if conditions remain the same. If the failure rate for the projected period increases over the failure rate for the current period, the economic impact could easily be much greater.

Figure 3-4. Florida P&L Unit Availability Report

- Preventive maintenance versus corrective maintenance (planned outages versus forced outages)
- Reliability design features and cost attributes
- Maintenance design features and cost attributes
- Extent of reliability engineering and test program.

AE firms rely on availability data (such as that from EEI/NERC) to perform the trade-offs and develop their plant designs.

Staff sizes range from a few in small organizations to over several hundred in the larger firms with the emphases primarily on quality assurance and analysis techniques for improving plant availability. Numerous technical articles have been prepared covering availability (and reliability) analysis techniques. Appendix E lists articles collected and reviewed during this study.

3.3 MANUFACTURER QA&R PRACTICES

The major manufacturers of electric power systems, equipment, and components plan and implement programs for ensuring basic quality and reliability of their products. The scope, methods, and rigor of the programs vary widely. The QA&R programs generally include performing highly disciplined engineering tasks to assess, identify, and correct design problems; applying special tests designed to improve reliability during development; and implementing quality control provisions to ensure reliability during system/component fabrication and plant construction. The scope of the manufacturers' activities is broad and includes the following interacting quality and reliability engineering elements:

- R&M design
- FMECA
- R&M prediction
- Critical item control
- Design review
- Failure reporting, analysis, and corrective action
- Reliability development (growth) testing
- Supplier audit and surveillance
- Configuration management
- Reliability demonstration
- Reliability acceptance
- Data reporting and feedback.

Most large equipment manufacturers rely on their own data (or data on their equipment and components provided by the operating utilities) in planning and implementing quality and reliability activities; they generally do not use broad generic data, such as that available from EEI/NERC. Emphasis is on identifying problems and corrective design action.

In general, manufacturers' quality engineering (QE) programs include systematic and timely management activities, engineering tasks, and controlled tests. The essential elements of their QA program are:

- Performance of detailed quality analysis, planning, and cost trade-off analyses
- Definition and implementation of a quality management and control program
- Application of systematic and highly disciplined quality engineering tasks during development and production that includes vendor selection, auditing, quality control, monitoring, inspection, and change control activities to identify and correct problems prior to equipment/component release for facility installation and operation
- Implementation of a field quality assurance follow-up program providing controls and procedures that allow a smooth transition from the manufacturing environment to the plant facility without degrading its reliability/quality level and that emphasize nondestructive testing at critical stages in the manufacturer/construction/operation process.

Quality requirements generally are derived from Military Specification MIL-Q-9858, which includes provisions covering:

- Quality program management
  - organization
  - initial quality planning
  - work instructions
  - records
  - corrective action
- Facilities and standards
  - drawing, documentation, and changes
  - measuring and testing equipment
  - production tooling used as medium of inspection
  - use of contractor's inspection equipment
  - advanced metrology requirements
- Control of purchases
  - responsibility
  - purchasing data
- Manufacturing control
  - materials and material control
  - production processing and fabrication
  - completed item inspection and testing
  - handling, storage, and delivery
  - nonconforming material

- Statistical quality control and analysis
  - indication of inspection status.

Although the specific requirements for each new generating unit or component are peculiar to that item, the approach to quality assurance for a given item varies somewhat with each manufacturer where the degree of applications is sometimes determined through cost/benefit analysis. There are numerous examples of the considerations and analyses made by manufacturers to develop an optimum plan for a given generating unit or component. These include:

- Sampling versus 100% inspection
- Extent of quality control during design and manufacturing
- Defect analysis and rework program
- Inspection level and expertise
- Special test and inspection equipment, fixtures, gauges, etc., versus general purpose equipment
- Prototype test and inspection versus full production control
- Quality of purchased material
- Extent of quality control audits and vendor surveillance
- Extent of new destructive testing.

Appendix E lists several papers that describe manufacturers' QA programs.

Many manufacturers also implement a reliability engineering program. Although a few organizations maintain a combined QA&R function, the reliability engineering program normally operates as a separate entity. The objectives of a manufacturer's reliability engineering program are to support design and development and help establish reliability that will meet specified requirements, to ensure that the "designed-in" reliability level is not appreciably degraded during fabrication and facility construction, and to track and control reliability throughout contract performance.

A major manufacturer's reliability engineering program, like its QA engineering program, is composed of systematic and timely management activities and engineering tasks. The essential elements of a typical reliability engineering program are:

- Performance of detailed reliability analyses and cost trade-off studies to establish optimum reliability and maintainability designs and parameters consistent with specified requirements during system design.
- Definition and implementation of a reliability management and control program. This program enables reliability personnel to influence design, provide timely outputs consistent with major designs and program decisions, and provides the means to develop power generating units and components that meet requirements cost-effectively.
- Continual application of systematic and highly disciplined reliability engineering tasks during the design phase to identify and correct problems prior to hardware build-up.

- Early reliability development and verification testing of critical equipment and components. The test program emphasizes failure analysis and corrective action and is based on a test cycle that reflects the actual power plant environments, including mechanical (vibration) stresses and temperature/humidity extremes.
- Implementation of a reliability assurance program during equipment/component fabrication and plant construction. This program includes controls and procedures that allows a smooth transition from design and development to construction degrading reliability that emphasizes "nondestructive" testing at critical stages in the overall fabrication/construction process.
- Performance of physical analyses of operational failure (in concert with the utilities) to identify and correct root causes.

As with QE program planning, many analyses are also performed to structure the most effective reliability engineering program. Table 3-5 details some of the reliability tasks considered by many manufacturers in determining the extent and level of their application and in structuring a reliability engineering program for new (or replacement) systems and components.

3.4 ELECTRIC POWER INDUSTRY TRADE ASSOCIATION QA&R PRACTICES

3.4.1 Edison Electric Institute/National Electric Reliability Council

Edison Electric Institute's (EEI's) objectives are:

- Helping electric companies generate and distribute energy at the lowest possible prices consistent with safe and reliable service
- Advancing the art of producing, transmitting, and distributing electricity, including the promotion of scientific research to meet user needs for electric power through environmentally acceptable means
- Gathering and making available factual information, data, and statistics important to consumers and the industry.

Until recently, EEI was the primary focal point for the collection and dissemination of availability data for electric power generating units, systems, and components. Nearly all utilities have participated, including investor-owned and public.

EEI availability data activities involved collecting three kinds of data: generating unit description, performance, and outage. Unit description data included unit type, size, start-up date, and fuel. They also included specific information on major components, such as tube material (for condensers), steam pressure at throttle at full load (for steam turbines), and speed at full load (for feed pumps). The number and manufacturer of major components were also included. Unit data were obtained when the unit was first started and when significant design changes were made. Performance data consisted of maximum dependable capacity, service hours, gross generation, and type of fuel burned. Outage data described events that curtailed power generation, including start and end time and cause and effect. Effect data, in the form of seven outage type codes, showed whether an outage was scheduled or forced, full or partial, or did not curtail generation. If the outage was partial, the power reduction was also reported. Information on cause was provided in the form of several hundred numbered codes. Examples are: 630, vibration of turbine generator unit, 715, generator inspection, and 916, maintenance error. Outage data were obtained quarterly.

Table 3-5. MANUFACTURERS' RELIABILITY ENGINEERING TASKS

Management—the organization, planning, control provisions, documentation, and definition necessary to carry out reliability tasks.

Reliability Allocation—subdividing system level reliability requirements down to component levels.

Reliability Prediction—estimating reliability based on conceptual models and historical data during the design and development process.

Failure Mode and Effect Analyses—an analytical part-by-part method to determine the consequences of potential failure on plant operation.

Component Control and Standardization—effort to select, specify, and control all "critical" mechanical, electronic, and electromechanical parts and components.

Design Review—formal evaluation of contractor effort with participation of cognizant subcontractor and utility personnel.

Reliability/Verification Testing—discover and correct failures, defects, or potential problems prior to plant operation based on destructive and nondestructive test methods.

Failure Analysis—determine causes of observed defects and report these findings for subsequent action.

Data Collection & Feedback—collect operational and maintenance data for feedback to management and design.

Reliability Assessment—determine the actual reliability based on plant operational data.

EEI published two annual reports. One summarized performance data: i.e., availability (operating and equivalent), capacity factor, and forced outage rate for the previous 10 years for plants of various sizes and types. The other summarized outage cause code data (for the same period), sizes, and types. Quarterly reports of large fossil unit performance and their significant outages were also published.

Effective 1 January 1979 EEI transferred to the National Electric Reliability Council (NERC) the responsibility for operating its equipment availability data system.

NERC was formed in 1968 with the stated purpose "to further augment the RELIABILITY and ADEQUACY of bulk power supply in the electric utility systems of North America." It consists of nine regional reliability councils and encompasses essentially all the power systems of the United States and Canadian systems in Ontario, British Columbia, Manitoba, and New Brunswick (see Fig. 3-5).

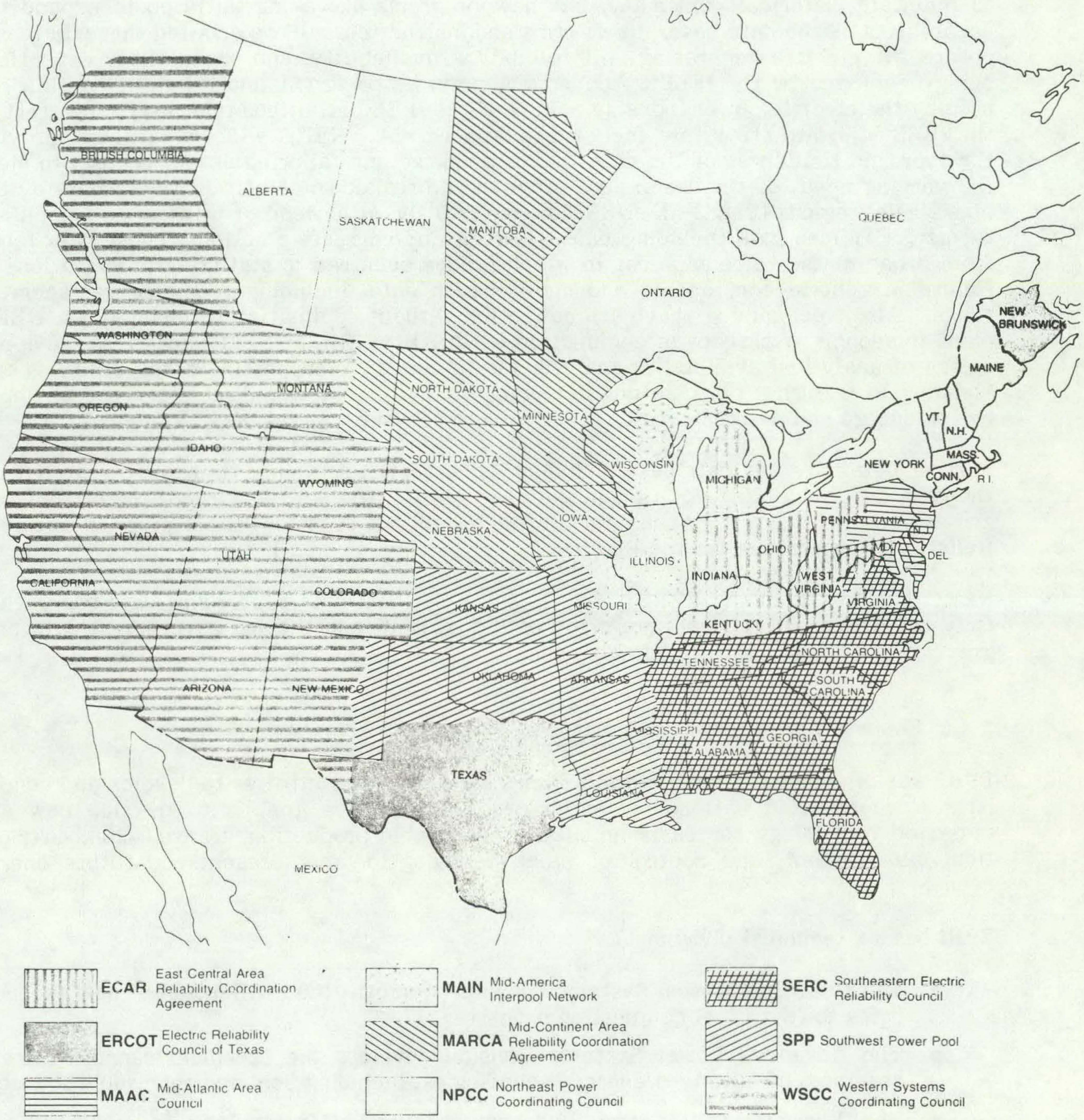


Figure 3-5. National Electric Reliability Council Regional Reliability Councils

As indicated previously, the equipment availability data system is the primary electric utility industry source for collecting, processing, analyzing, and reporting power plant outages and overall performance. Much of the EEI program will be continued by NERC to maintain historical continuity, but new programs are being initiated to expand the capabilities of the data base. New forms and instructions will be adopted that will incorporate the electric generating unit reliability, availability, and productivity definitions being developed by the IEEE. Appendix A provides basic QA and reliability definitions used by the electric power industry. Many of the IEEE definitions that are in the draft of the IEEE Standard (1979) are included in Appendix A. NERC will emphasize improving the type and timeliness of the data that is acquired and tailoring output reports to meet the varying needs of the users: e.g., providing a breakdown of unit summary data by the nine NERC regions (Fig. 3-5). NERC recognizes the vital need of utilities and manufacturers for failure data including causes, rates, and corrective actions. These data range from broad classes of equipment in which failure occurred to statistical distributions of failure in generic components and maintenance data, including repair or replacement times. Also, recognizing that data collection without application is meaningless, NERC plans to support workshops in conjunction with DOE, EPRI, and EEI that stress the application of analytical availability analysis and the need for supporting data. NERC is also planning to publish a periodic newsletter or brochure that will discuss the use of application outage and performance data for solving design or operational problems.

Further details on the data base including its current status since its transition to NERC, the data base rebuilding program initiated by NERC, the new data reporting procedures, and anticipated changes to the data are described in a technical paper given at the 1979 Reliability Conference for the Electric Power Industry (Neibo 1979).

NERC is also supporting EPRI in developing a national data base. This data base, when fully developed, will consolidate many of the current industry and government data programs into a single centralized data base.

3.4.2 Electric Power Research Institute

EPRI was organized in 1973 by the nation's electric power utilities to develop and administer a coordinated national research program. EPRI's goal is to develop new and improved technology for environmentally acceptable production, transmission, distribution, management, and control of electric power to meet present and future energy needs.

EPRI has six technical divisions:

- The Coal Combustion Systems Division promotes the application of new technologies to fossil fuel combustion processes.
- The Advanced Power Systems Division develops the technical capabilities and readiness of advanced energy technologies, including coal and renewable sources.
- The Energy Analysis and Environment Division is involved in environmental assessment, energy supply, and energy demand concerns.
- The Energy Management and Utilization Division performs research studies in the areas of electromechanical energy conversion (i.e., fuel cells), batteries and other storage systems, and conservation (solar energy heating and cooling).

- The Nuclear Power Division area of research includes safety and analysis, nuclear engineering, plant operations, and nuclear systems and materials.
- The Electrical Systems Division includes research for overhead and underground transmission and distribution systems, power delivery equipment, rotating electric machinery, and improved methods for power system planning and operation.

The utilities supporting EPRI provide guidance relative to the research needs of the industry. Power generating availability and system reliability are major needs of the utilities and, consequently, are key areas at EPRI. EPRI is active in:

- Developing consistent definitions and procedures for collecting power system component outage data and methods for forecasting outage statistics
- Developing meaningful indices and practical methods for assessing generation and transmission system reliability
- Developing methods for assessing direct and indirect costs of power interruptions and for cost-benefit evaluation of reliability.

The following paragraphs briefly describe some of the projects at EPRI relative to these areas.

Reliability Measures for Power Systems: The objective is to develop measures or indices of power systems' reliability that: (1) are suitable in making a consistent evaluation of the overall system reliability from generation to distribution; (2) can be used in assessing the value of reliability to customers; and (3) can be readily understood by nontechnical people.

Bulk Transmission System Component Outage Data Base: The objective is to develop consistent definitions and procedures for use in outage data collection for bulk transmission system components and to organize a comprehensive data base that will meet industry needs for U.S. utilities. This work is not aimed at the collection of data, but the research results would be useful to any organization charged with data collection.

Fault Tree Analysis for Reliability Prediction of Gas Turbine Type Power Plants: The objective of this project is to determine whether fault tree methods could be used to predict the reliability of a fossil fuel power plant. As a test case, a fault tree model was developed and evaluated for an existing gas turbine power plant. The overall plant reliability prediction for producing steam over 500 consecutive hours was 0.965. This value was considered reasonable by utility personnel, and it was concluded that the fault tree technique is useful for this kind of reliability prediction.

Generation System Reliability Analysis for Future Cost/Benefit Studies: The major emphasis of this project is on developing a new method for calculating the frequency and duration of emergency procedures. The ultimate objective of this cost/benefit analysis is to determine the optimal level of reliability by combining customer costs and customer loss of benefits.

Effect of Operating Considerations on Reliability Indices Used for Generation Planning: A detailed Monte Carlo simulation computer program was developed to consider the impact of a great variety of operating details, constraints, and policies on generation reliability performance and to investigate the effect of these factors on computed reliability indices. A system of 513 generating units was used to study the relationship of actual historical reliability performance to that predicted by both a conventional analytic method and the Monte Carlo method.

The Role of Personnel Error in Power Plant Equipment Reliability: The effects of personnel errors on the equipment availability of a cross section of fossil fuel power plants are quantified. The data are based on a questionnaire, personal interviews, and trouble memos of two utilities. The report indicates that personnel errors are responsible for at least 20%-25% of all failures in power plant generation systems.

In addition EPRI is conducting an ongoing multitask research program for improving reliability and performance of new and existing fossil fuel power plants (Poole 1980). The program deals with turbine generators, steam generators, plant auxiliaries, and plant chemistry, as well as the overall integrated plant. Design guidelines have been generated that can be used by the utilities to evaluate and specify components.

EPRI also has recently conducted a series of studies on the adequacy of existing power plant performance/reliability data bases (Koppe and Arnst 1978; Koppe 1979; Holmes and Narver 1978; Stone & Webster Engineering Corp. 1979). These studies have concluded that the need exists for extending and consolidating all power plant reporting systems into a single national data collection system that will be more responsive to the needs of the utilities.

The national data collection system is currently under development. It is envisioned that its scope, once fully developed and operational, will be limited to power plant performance, unit outage, and component failure data.

Performance data would include energy generation, service hours, capacity factor, etc. Outage data, including forced and planned outage rates, would represent the primary thrust of the system but with increased emphasis on reporting outage causes, on including noncurtailing failures (i.e., component failures that do not result in an outage), and on reporting more rapidly with the integration of an early alert system that concentrates on problems that cause outages and/or affect major components. Component data involves recording and collecting descriptions of individual failure (i.e., running time, number of cycles, failure modes, repair time, maintenance time) to determine failure rate, mean time between failures, and mean time to repair generic components. It is anticipated that all utilities will report performance statistics with only the larger utilities reporting outage data and only those utilities (such as Florida P&L and Ontario Hydro) that have an internal computerized maintenance work order data system reporting component failure. Translators would convert diverse data from the utilities for use at the national level.

It will take several years to develop and demonstrate the system, which will then be managed by an industrial organization such as NERC.

3.5 DOE QA&R PRACTICES—FOSSIL ENERGY PERFORMANCE ASSURANCE SYSTEM

Recognizing its responsibilities under P.L. 95-91 in which DOE is charged to "increase the efficiency and reliability in the use of energy," and in an effort to attain National Energy Goal Number IV to "increase the efficiency and reliability of the processes used in energy conversion and delivery systems," DOE/FE is establishing and implementing a formal performance assurance system (PAS) for their fossil energy research, development, and demonstration (RD&D) projects.

PAS is essentially a management technique to help achieve the early, reliable, and cost-effective performance of fossil plants. It consists of systematically applying design considerations, data collection, analysis, and communication networks and procedures.

The disciplines incorporated in PAS are reliability, maintainability, quality assurance, configuration management, availability, operational service life, life-cycle costs, safety engineering, and standardization. These disciplines have been chosen for their applicability to fossil energy programs, emphasizing early identification and solving of problems that would delay or decrease reliable, economic development if not addressed in a timely, systematic manner. PAS prime objectives are to reduce cost and increase the effectiveness of a project.

There are several fossil energy projects at or near the demonstration stage of development. Seven projects were selected as potential candidates for initial implementation of PAS activities, because they had advanced to the demonstration stage. Thus, these seven projects were those that could benefit most from near-term implementation of PAS.

The seven programs selected are compared on a relative basis in Table 3-6. The information shown is a summary of each program's activities including some factors affecting the PAS implementation schedule.

PAS is designed to apply to all process maturity levels, from the small process development unit to the large demonstration plant. The Performance Assurance Program will be tailored to each project using basic criteria, such as maturity level, dollar value, technical feasibility, and commercialization potential, in determining the exact scope and size of the program.

The goals of the system are accomplished through a PAS Office. This central agency acquires, generates, maintains, and disseminates information. It also makes available procedures, tools, and systems to ensure that system availability, life-cycle cost, and the other performance assurance elements are adequately treated in the development, construction, and operation of fossil energy RD&D systems. The PAS Office provides technical support to project managers and contractors on an as-needed basis. PAS will be able to perform independent RAM assessments, life-cycle cost estimates, and special studies as required. PAS can assist project managers in evaluating contractor PA programs and conducting program/design reviews.

The Fossil Energy Equipment Data System (FEEDS) is being established for the collection evaluation, and storage of data on the failures, operability, and maintenance of fossil energy components and materials. It will also analyze and disseminate this information to assist architect engineers, technicians, and managers in the selection, assessment, operation, and maintenance of fossil energy components and systems (see Fig. 3-6). FEEDS will be physically located at the National Bureau of Standards (NBS). The FEEDS Operations Office at NBS will receive, screen, and input information into computer and microfilm data banks. Personnel from the NBS Failure Analysis Program analyze and evaluate failure reports and failed components and materials and prepare reports as appropriate. FEEDS will use Government-Industry Data Exchange Program (GIDEP) information processing equipment and personnel (at Corona, Calif.) to store and disseminate failure, operability, and maintenance data to PAS/FEEDS participants. A further description of the FEEDS System and the responsibilities of the participating agencies is given in Appendix B.

Table 3-6. CANDIDATE DEMONSTRATION PLANTS[a]

Location	Program Description	Estimated Cost[b] (M$)	Industry Partner	AE	Start Date (1977)	Completion Date	Current Status
Noble County, Ohio	Design, construct, and operate demo plant using fixed bed gasifier to produce pipeline-quality gas	T 372.7 D 22.7 C O 350.0	Conoco	Foster Wheeler	May 27	Beyond FY 1983	Developing conceptual designs and economics of commercial plants, conceptual designs of demo plant and conducting confirmation tests in pilot plants (overseas)
Cutler, Illinois	Design, construct, and operate demo plant using COED[c] coal pyrolysis and char air-blown gasifier concepts to produce pipeline gas	T 334.00 D 25.1 C O 308.9	Illinois Coal and Gas	Dravo	June 7	Beyond FY 1983	
To Be Determined	Conceptual design of commercial scale plant using Hygas process to produce pipeline-quality synthetic gas	T 7.5	None	Procon	July 29	Beyond FY 1983	Conceptual design of commercial-scale plant almost complete. If promising, will develop economics and conceptual design of demo
Tennessee	Design, construct, and operate demo plant using a fluidized-bed O_2-steam gasification process at 90 psig producing/delivering 50 billion Btu/day of industrial fuel gas	T 179.5 D 6.5 C 173.0 O	Memphis Light, Gas and Water	Foster Wheeler	Aug. 30	FY 1983	Conceptual design of a 2800 t/d low Btu fuel gas demo plant
Western Kentucky	Design, construct, and operate a demo plant producing synthesis gas for NH_3 production	T 318.4 D 10.2 C 308.2 O	W. R. Grace & Co.	Ebasco/ Humphries and Glasco	Aug. 26	Beyond FY 1983	Conceptual design of a 1700 t/d plant producing 1200 t/d NH_3

Table 3-6. CANDIDATE DEMONSTRATION PLANTS[a] (Concluded)

Location	Program Description	Estimated Cost[b] (M$)	Industry Partner	AE	Start Date (1977)	Completion Date	Current Status
Hoyt Lakes, Minnesota	Design, construct, and operate a two-stage fixed-bed air-blown gasifier to produce fuel gas for drying/hardening Taconite pellets	T 52.2 D 9.2 C O 43.0	Erie Mining Company	Arthur McKee	Oct. 19	FY 1982	Phase I Conceptual Design of a small-scale, low-Btu Fuel Gas demo project
To Be Determined	Design, construct, and operate a demo plant using solvent extraction process	T 7.5 D 7.5		Gulf Oil Corp.			Phase I Conceptual Design

[a]The design phase is fully government funded with the 50-50 cost shared with industry from procurement to construction, operation, and evaluation.

[b]T = Total
D = Design
C = Construction
O = Operation

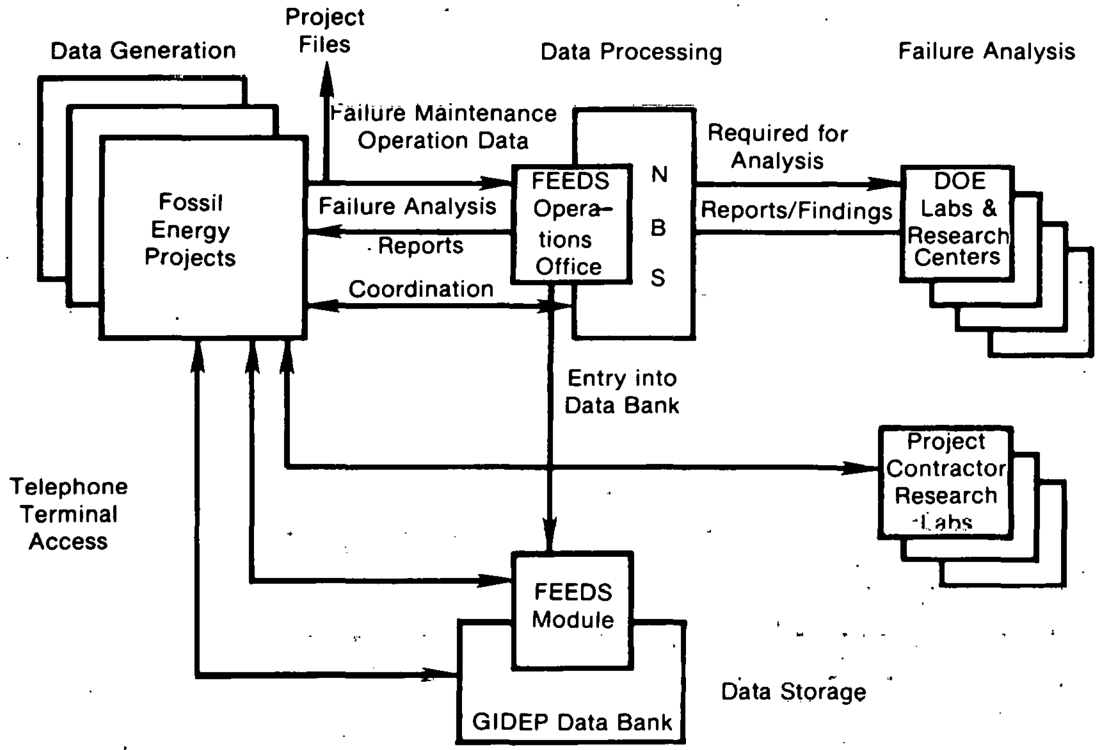


Figure 3-6. Fossil Energy Equipment Data System (FEEDS)

Technical and management-oriented documentation is to be used by fossil energy project managers and contractors in contracting for planning and implementing performance assurance in fossil energy contracts. This includes:

- Fossil Energy Performance Assurance System Manual for Project Managers. The manual provides DOE/FE officials with a comprehensive description of PAS, its philosophy, objectives, and general methods of application. It also includes guidance for using the resources provided by FE/PAS to best advantage within the context and constraints of individual fossil energy projects.
- Guidelines for Incorporating Performance Assurance Requirements in Fossil Energy Research, Development, and Demonstration Contracts. The guidelines include specific language that can be used verbatim, in whole or part, as statements of work in fossil energy procurement and contractual documents.
- Fossil Energy Performance Assurance Handbook. The handbook describes recommended methods and procedures for applying each relevant performance assurance discipline during each state of a system's life cycle.

A training program familiarizes fossil energy officials and contractors with the concepts and methods of performance assurance.

As presently conceived, the full-scale application of performance assurance to an R&D project includes the following activities:

- Identifying performance assurance requirements tailored to the needs of the particular project under consideration

- Developing and documenting a performance assurance program plan
- Establishing quantitative goals for key performance assurance parameters (e.g., system availability, life-cycle cost)
- Maintaining planning and engineering
- Analyzing availability/life-cycle cost engineering
- Including performance assurance considerations in design reviews
- Establishing a formal quality assurance program
- Establishing a formal configuration management program
- Establishing formal mechanisms for the collection, analysis, storage, and dissemination of failure, maintenance, and operability data.

Use of FE/PAS or any subset of its program is available to each FE project manager.

Conceptually, PAS has been developed as a support service. Project managers continue to exercise full management control, supervision, and responsibility over all aspects of their individual PA programs.

PAS is intended to provide the following:

- The identification of all reliability, maintenance, and cost-critical items in a plant/project and the recording/documentation of the performance of these items throughout the design, construction, and operation phases
- Properly identified and documented failure modes of these critical items
- Actions to enhance plant operability (i.e., redundancy, improved maintenance, improved quality)
- Life-cycle cost analysis
- Service life estimations of equipment/components
- Standardization through use of common items/materials
- Properly documented and updated plant configurations
- Operation/maintenance procedures
- Suitably monitored and documented materials
- Complete plant/project operability data.

3.6 OPERATIONAL RELIABILITY LEVELS

A concerted analysis and study of availability and outage data, as compiled by EEI, NPRDS, and NRC, would be required to completely represent achieved reliability levels and trends for power-generating systems and components. This is beyond the scope of the present study. Instead, results of analyses performed by others will be presented. Although perhaps sketchy, these data do give a gross indication of the levels being experienced by the industry.

Most available reliability data are based on results observed over several years and do not include the most recent years. Thus, it is difficult now to measure the improvement resulting from the formal reliability program efforts that have been instituted within the past several years.

Operating availability and forced outage rates by general type of generating system are presented in Table 3-7. These data were compiled by EEI for a 10-year period (1966-1975). They summarize results observed for all systems tracked over this time period, which consisted of 13,603 unit years of generating system operation. Forced outage rates for gas turbines, jet engines, and diesels are substantially higher than those for other generating systems although operational availability is at the same approximate level. This apparent anomaly exists because these generation systems are used only to accommodate peak load demands; hence, their time in service is low relative to the time required to effect repairs when an outage does occur.

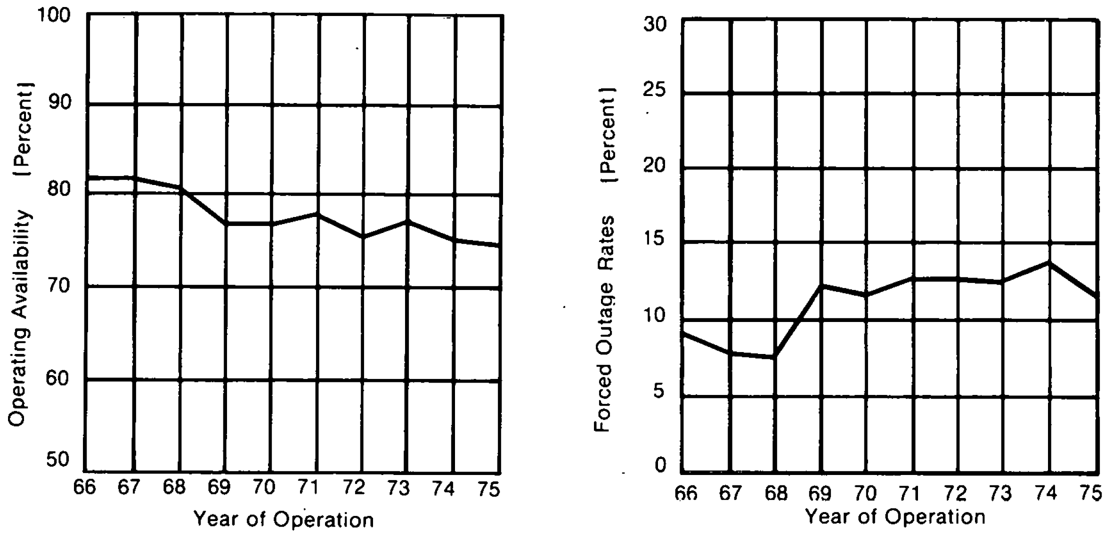
The fossil unit reliability level as a function of calendar year exhibited a negative trend over this 10-year time period as illustrated in Fig. 3-7, which was taken from the same EEI data compilation. Perhaps part of this trend can be explained by generating unit size. In an effort to achieve operating economies, operating unit sizes increased continually until it was discovered in the late 1960s and early 1970s that operational reliability suffered as capacity increased, especially beyond 600 MW. This relationship is depicted in Fig. 3-8. Subsequently, unit size has leveled. More current data would be required to assess the effects of this change in philosophy.

Table 3-7. AVAILABILITY SUMMARY: 1966-1975
(Unit Year Averages)

System Type	Unit Years	Operating Availability (%)	Forced Outage Rate (%)
Fossil	6933	85.5	5.58
Nuclear	168	74.4	12.62
Gas Turbine	2812	86.5	35.22
Jet Engine	1394	85.7	43.01
Diesel	1186	95.0	28.33
Hydro	932	95.0	1.59
Pumped Storage	161	87.0	11.69
Other	17	80.4	7.13

Source: Edison Electric Institute (1976).

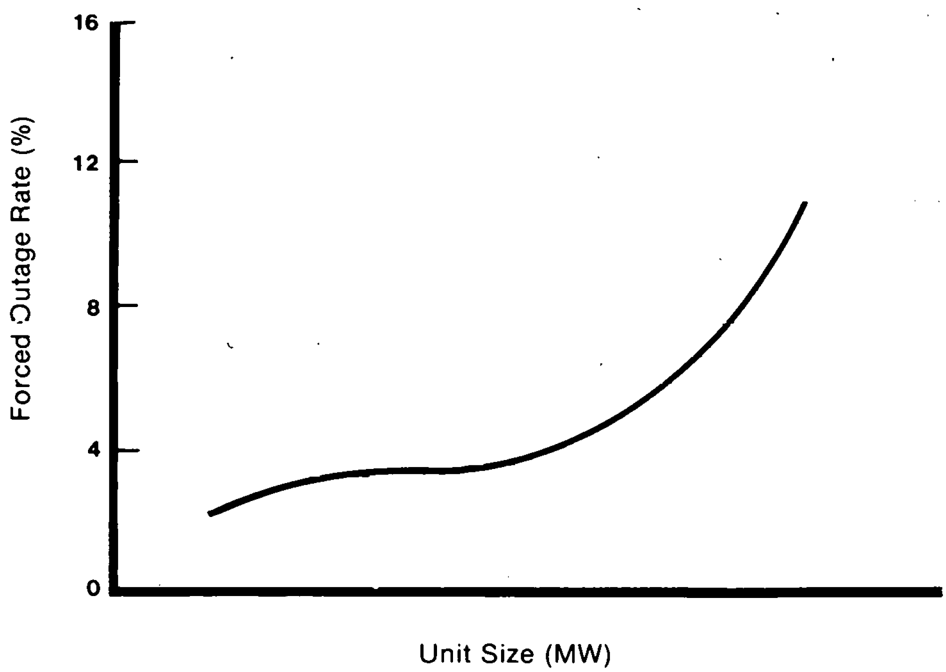
Within a fossil-fueled generating system, the boiler, turbine, and generator are the major contributors to forced outages. Boilers are particularly vulnerable. Although several parallel turbines and generators each carrying a portion of the load may be used in a generating unit, they are driven from a single boiler. Thus, a boiler failure causes a complete forced shutdown. In addition, boilers characteristically exhibit high failure rates and require lengthy repair times. Walters (1979) reported that a study by EPRI indicated that boilers, turbines, and generators accounted for 90% of forced outage hours in systems of 390-599 MW and 92% in systems of 600 MW capacity or greater. The relative contribution to forced outage rate by system component is shown in Fig. 3-9 as a function of generating unit size. Bickerdike (1979) reported on a six-year study of 258 hydro generating systems in which a total of 4,753 failures were observed. Of these, turbines and generators accounted for 1,027 or about 22% of the observed failures



(Plots include fossil units with capacity ratings ≥400 MW)

SOURCE: Edison Electric Institute 1980.

Figure 3-7. Fossil Generating System Reliability vs. Calendar Year of Operation



SOURCE: Electric Power Research Institute 1976.

Figure 3-8. Forced Outage Rate vs. Unit Size

However, the forced outage caused by these failures amounted to 50.4% of the total system shutdown hours.

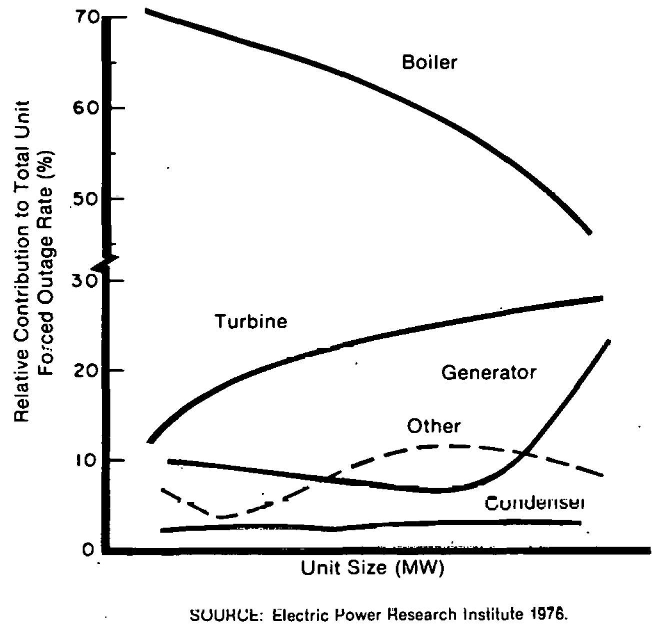


Figure 3-9. Forced Outage Rate of Major Components

As is typical of hardware systems, the power generating industry has experienced substantial variations in reliability between systems and system components. As an example, Walters (1979) reported that the forced outage rates for 54 turbine generators used in nuclear plants with a capacity of greater than 450 MW averaged 3.3% but ranged from less than 1% to over 10% for individual units. The causes of these differences are difficult to isolate since there are unit-to-unit variations within a given manufacturer's output, product variations between manufacturers, and variations between generating facilities.

In summary, large power generating plants can be expected to be unavailable approximately 15% of the time with boilers, turbines, and generators being the greatest cause. Reliability is inversely related to system output capacity and is highly variable from unit-to-unit. Reliability improvements resulting from stabilizing generator sizes and reliability program efforts are not yet discernable from available data, but expectations range to a 10% improvement over the next 5-10 years.

SECTION 4.0

CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to establish a thorough understanding of the QA&R practices that the electric power generating industry found to be most effective in achieving high levels of hardware reliability and electric power availability. The results of this study are intended to be used by the DOE PV program to develop long-term QA&R requirements and plans for PV power generating systems. Further, the results are to provide direct input into near-term SERI activities that are part of the validation methods development task of the performance criteria and test standards project.

Contacts, including in-depth technical discussions, were held with representatives from all segments of the industry including the utilities, AE firms, hardware manufacturers, trade associations, and others active in QA&R program activities.

Results of the study indicate that a full spectrum of QA&R activities are applied by the industry to ensure the basic quality and reliability of the electric-power generating units and equipment.

Many of the reliability-oriented efforts are only now being, or have recently been, implemented; therefore, the full impact of their effect has not yet been realized. Further, because of the relative newness of reliability activities within the power industry, a large amount of experimentation and investigation of different approaches and techniques is still needed to achieve optimum results. Thus, from a reliability point of view, the industry is in a state of flux. Many programs and practices are still in a shakedown period with substantial changes in approaches, methods, techniques, and procedures likely to occur over the next 5-10 years.

In spite of its immature state, certain trends have emerged from which the PV program can benefit. Some of the conclusions that may be drawn from the study include:

- The industry, including hardware manufacturers, is familiar with formal RAMS (Reliability, Availability, Maintainability, Safety) programs and program elements. This can materially reduce the time and effort needed to educate and orient management and engineering personnel on the benefits and applications of this control discipline.
- The power industry is finding that these RAMS programs are cost-effective; in fact, the primary justification for their application is to achieve cost savings.
- RAMS efforts are most effective during component/system R&D phases where the discipline enables designers to identify and correct potential design, safety, or performance deficiencies prior to spending large resources for demonstration hardware.
- There is no single standard sequence of RAMS program functions or tasks that is applicable in all situations. Instead, each program, organization, or system application must evaluate its peculiar needs and tailor a program that will provide the elements considered essential for achieving the stated objectives.
- From its experience with fossil energy power systems DOE is finding that it is essential to establish program-wide minimum RAMS performance standards with appropriate emphasis on centralized management, support, and monitoring of the

program. A key aspect of this experience is the application of RAM guidelines in lieu of requirements, particularly during early stages of a program.

Working within the framework of these findings, many of the specific practices, such as QA&R audits and surveillance, program control methods, unit/system availability and hardware reliability methods, and data recovery and feedback techniques, can be readily adopted or can provide a baseline to formulate appropriate PV QA&R efforts.

Based on the value of the QA&R practices revealed by this study and currently applied by the power-generating industry, the following recommendations are presented as they apply to SERI's Performance Criteria and Test Standards Program.

We recognize that many of these activities already are being performed at various intensities within the DOE PV program on some system elements (most notably PV cells and modules).

4.1 DEVELOPMENT OF RELIABILITY PREDICTION MODELS AND ANALYSIS TOOLS

Basic prediction models and analysis tools should be developed and procedures, complete with forms and data for implementation, should be prepared. The analysis tools should be based on availability and reliability analysis procedures that specifically reflect PV systems and failure characteristics (i.e., failure due predominantly to PV module degradation) and long-term environmental application factors. Critical to the development of a PV availability/reliability model is the definition of failure. Definition and analysis techniques, including loss of load probability (LOLP), operating availability, outage rate, capacity factor, derating (seasonal), etc., used by the conventional electric power industry (see Appendix A) provide baseline information for defining failure relative to PV applications and for formulating a reliability method. Several analysis tools can be formulated, such as reliability prediction, failure modes and effects analysis (FMEA), fault tree analysis (FTA), and design review, once a PV model and overall method have been established. Procedures used by the industry can be tailored to meet the needs and constraints of the PV program. An overall method, such as the input-output model developed by Florida P&L, can be structured that provides specific procedures and criteria for residential PV systems or other applications that would be useful to the PV community in the near term.

4.2 ESTABLISHMENT OF PV QA&R PROGRAM PROVISIONS AND REQUIREMENTS (NEW PROCUREMENTS)

Development of a document providing cost-effective QA&R criteria and procurement guidelines that stress the importance of clearly defined hardware procurement specifications would help the goals of the PV program to be met. The document could be similiar to DOE's Performance Assurance System Specification Guide that can be readily incorporated into procurement specifications. The document would provide a basis for selecting and/or tailoring procurement requirements to fit the unique needs of any PV project application.

QA&R provisions based on a matrix approach similiar to Consolidated Edison's quality assurance (see Appendix D) and Ontario Hydro's reliability requirements that present several levels of quality assurance and reliability have merit and should be considered. QA&R levels are determined by several pertinent factors, such as configuration and complexity, application, and contractor experience. The guidance document should include provisions and requirements for:

- Reliability allocation, prediction, and assessment
- Failure modes and effects analysis
- Parts control
- Critical item control
- Production degradation control
- Design review
- Supplier audit and surveillance
- Quality assurance and reliability testing
- Failure reporting, analysis, and corrective action.

The program required would be, to a large extent, a function of PV type and end use. The more complex the system and the more stringent the application, the more extensive the required program would be. The QA&R program matrix could reflect several levels of intensity based on PV type and application. Sample QA&R requirement programs can be formulated corresponding to the provisional combinations defined in the matrix that would be suitable for incorporation into PV procurement specifications. Similiar to the approach taken by Ontario Hydro, specific QA&R provisions can be defined covering quantitative and qualitative design, program, and acceptance requirements for the major PV type and application classes, recognizing cost constraints. Life-cycle cost (LCC) analysis, similiar to that performed by the Bonneville Power Administration, can be applied to determine a given PV class reliability level (quantitative and qualitative) that would minimize life-cycle cost and could be incorporated into the guidance document. However, QA&R requirements for a given hardware procurement must be adapted to meet its needs and constraints; sample requirements would only aid in formulating procurement requirements by providing consistent and uniform criteria and guidance.

Initial efforts should define the extent and intensity levels of the provisions and requirements for residential PV systems. Then, consistent with PV system development priorities, QA&R provisions and requirements could be defined for other PV system applications and integrated into the matrix, the sample requirements, and the overall guidance document.

4.3 PREPARATION OF A GLOSSARY OF QA&R TERMS APPLICABLE TO SOLAR ENERGY SYSTEMS

Development of a glossary that provides common language definitions and formula will provide a much needed input in developing QA&R program requirements, methods, and validation criteria, and, in particular, provide a basis for information exchange, thus permitting accurate reporting and analysis of the reliability and quality of experimental and demonstration PV systems and components. The definitions compiled during this study and presented in Appendix A represent a start in developing a glossary that specifically meets the needs and characteristics of the PV community.

4.4 DEVELOPMENT AND ESTABLISHMENT OF AN EFFICIENT AND USEFUL PV QA&R DATA RECOVERY ANALYSIS AND FEEDBACK SYSTEM

Development of a formal and well documented data recovery, analysis, and feedback system is a key element in an effective QA&R program. The data recovery and feedback program should compile data from manufacturing, installation, and field operations. Data summary forms should be prepared that allow development of output information that can be used for:

- Reliability and quality assessments
- Reliability tracking
- Comparative analysis and assessments
- Determination of the effectiveness of QA&R activities
- Identification of critical components and problem areas
- Compilation of historical component failure rates for early design predictions.

In addition, as part of the data recovery program, a formal, systematic, and well-documented failure reporting and analysis and corrective action system should be implemented. The system should determine the root cause of failure resulting from design, manufacture, operation, or maintenance. The system should emphasize the investigation and analysis of all failures (or problem areas) regardless of their apparent magnitude. The system should classify failure according to design, procurement, manufacture, application, and field environment. Standardized forms for failure reporting, analysis, and corrective action should be adopted. The utilities, EEI/NERC, and DOE data recovery and feedback methods (as well as the National Data System currently being designed by EPRI) including data forms, procedures, and data management schemes discussed in this report should be evaluated in depth for possible PV application.

4.5 ESTABLISHMENT OF REALISTIC QA&R TESTING PROCEDURES

Application of cost-effective QA&R tests during PV hardware system development is essential to ensure reliability growth and demonstrate compliance with specified requirements. A QA&R test program could be structured to emphasize the performance of reliability and quality tests at key points during the design, development, and production/construction cycle. To be most cost-effective, an integrated test program complete with criteria and test methods should be planned and implemented early in the PV system acquisition process. The considerations and cost trade-offs made by manufacturers of conventional power systems and components in planning their QA&R test programs should be evaluated to help formulate a PV QA&R test program. Trade-offs should be made considering such factors as test flow, test duration versus confidence, test environment, sampling versus 100% inspection, prototype versus production tests, and the extent of nondestructive testing (NDT). The test program should emphasize development and verification testing of critical components, nondestructive testing at critical stages in the development/construction process, and failure analysis and corrective action. It should be based on test cycles that reflect actual PV applications and environments and, in particular, long-term mechanical stresses and climatic extremes applicable to residential PV systems.

4.6 QA&R PROGRAM SUPPORT AND COORDINATION

In addition, it is also recommended that formal programmatic engineering QA&R support be provided to new projects, procurements, and field installations, based on the above guidelines, definitions, and methods. The support should include:

- Performance of QA&R cost benefit studies to establish requirements for new procurement, assess LCC, and identify critical areas (based on predictive models, Sec. 4.1 using historical component failure rate data, Sec. 4.4)
- Evaluation, audit, and monitoring of contractors' QA&R program efforts during design, development, production, and site installation (based on guidelines included in the QA&R provision and requirement document, Sec. 4.2)
- Performance of independent analyses and special studies as necessary to determine ways to improve reliability
- Review and evaluation of test plans and procedures (based on predetermined criteria and test methods previously mentioned), and coordination of failure analysis activities (based on formal data recovery and analysis procedures, Sec. 4.4)
- Coordination of field data collections including data reduction, identification of items having high failure rates or that require excessive maintenance, and preparation of statistical summaries
- Assessment and tracking of reliability based on field operational/failure data
- Identification of critical components, failure modes, and causes based on analysis of the field data and failure reports
- Development and implementation of a formal indoctrination and training program in the application of basic QA&R tasks to project engineers, contractors, test operators, and others active in PV planning, design, test, and demonstration.

All of these task elements are applicable for PV electrical power systems regardless of end use. Differences obviously exist because of system size, complexity, and consequences (cost, safety, etc.) of outage that must influence the sophistication and depth of treatment in applying the suggested techniques to specific situations. General rules relative to the several application sectors should be made part of the developed requirement, technique, or procedure, but responsibility for specific adaptations to a particular program, organization, system, or product must remain with the responsible engineer.

To provide cohesiveness and continuity of QA/RAM activities among the several program elements and demonstration projects within the PV program, it may be advantageous to establish program-wide minimum QA/RAM performance standards. Building on the DOE fossil energy system experience, a centralized management approach for this important program function should be considered. A logical first-step would be formulating an overall PV program QA/RAM policy and plan. This would lay the foundation for an integrated, uniform, and effective application of QA&R initiatives currently being pursued within the PV program and the specific task activities recommended in this report. The policy/program plan would emphasize a total life-cycle approach that includes tasks and control provisions that start during the early design of a PV system and continue through development, production, demonstration, and field application. The plan would delineate objectives and criteria for timely and cost-effective implementation of the recommended task activities as they correspond to critical PV system life-cycle stages. It would include specific plans and milestone schedules for the development and implementation of appropriate standards, procedures, and guidelines that would fully describe the tasks and control provisions, define the QA/RAM method as structured for PV systems, and provide techniques for implementing methods to perform trade-offs between reliability and cost.

An essential element of the QA/RAM plan would be to provide specific plans for implementing an adequate data system that provides a measurement of field reliability, permits the evaluation of specific design decisions early in the design cycle, provides a basis for determining cost-effective requirements for hardware specifications and, in general, provides data to support the life-cycle tasks delineated in the plan. Development of an overall PV program QA/RAM policy and plan would not only ensure maximum visibility of reliability achievements and deficiencies but, based on experiences of the conventional power-generating industry, should result in the development and demonstration of reliable, safe, and cost-effective PV systems at lower cost with fewer schedule delays.

SECTION 5.0

REFERENCES

Bickerdike, C. G. 1979. "Modes of Failure in Hydroelectric Generators." Presented at the 6th Annual Reliability Engineering Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

Consolidated Edison. 1972. "Quality Assurance Requirements." Specification QA 7100. New York.

Edison Electric Institute. 1976. Report on Equipment Availability for the Ten-Year Period, 1966-1975. Publication No. 76-850. Princeton, NJ.

Electric Power Research Institute. 1978. Requirements Assessment of Photoelectric Power Plants in Electric Utility Systems. Vol IV. #ER-6850. Palo Alto, CA.

Holmes and Narver Inc., 1978 (Mar.). Power Data System. Palo Alto, CA: Electric Power Research Institute.

Koppe, R. H; Arnst, G. S. 1978 (July). Consolidating Power Plant Data. Palo Alto, CA: Electric Power Research Institute.

Koppe, R. H. 1979 (Feb.). Power Plant Early Alert Reporting System. Palo Alto, CA: Electric Power Research Institute.

Neibo, R. J. 1979. "Transition of Equipment Availability Data System to NERC." Presented at the 1979 Reliability Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

Nuss, G. R. 1979 (Aug.). Interim Implementation Structure for Development of Criteria and Test Standards for Photovoltaic Systems. SERI/MR-61-270. Golden, CO: Solar Energy Research Institute.

Poole, D. N. 1980 (Apr.). "Fossil Plant Performance and Reliability—A Many Faceted Component Improvement Program." Presented at the 7th Annual Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

Institute of Electrical and Electronics Engineers. 1979 (Mar.). Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity. Prepared by Power Plant Productivity Definitions Task Force, Application of Probability Methods Subcommittee, Power Systems Engineering Committee. New York.

Stone & Webster Engineering Corp. 1979. Analysis of Utility Industry Data Systems. Palo Alto, CA: Electric Power Research Institute.

Vanderzanden, W. R. 1980 (Apr.). "The Economics of Power Transformer Reliability-Reliability Improvement by Profit Incentive." Presented at the 7th Annual Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

Vessely, J. E; Cowdery, J. W. 1980. "RAM—A Management Challenge." Presented at the 7th Annual Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

Walters, R. J. 1979. "Realizing Reliability." Presented at the 6th Annual Reliability Engineering Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

Zagursky, G. P.; Pillar, C. S. 1980. (Apr.). "A System Approach to Reliability Program Development and Implementation." Presented at the 7th Annual Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

APPENDIX A

QUALITY ASSURANCE AND RELIABILITY DEFINITIONS

(as applied to electric power generation systems)

This appendix contains terms and definitions identified through a review of documentation and information compiled during the study. The Institute of Electrical and Electronics Engineers (IEEE) currently is developing a standard for electric generating unit reliability, availability, and productivity terms and definitions. Many of the terms and definitions included in the draft of the IEEE Standard* are incorporated in this appendix.

Accelerated Test—A test in which the applied stress level is chosen to exceed the level stated in the reference conditions to shorten the time required to observe the stress response of the item or magnify the response in a given time. To be valid, an accelerated test must not alter the basic modes and/or mechanisms of failure or their relative prevalence.

Acceleration Factor—The ratio between the times necessary to obtain a stated proportion of failures for two different sets of stress conditions involving the same failure modes and/or mechanisms.

Adequacy- Sufficient generating capability to meet the aggregate peak electric loads (MW) and energy requirements (MWh/h) of all customers at all times.

Availability—The probability that a material, component, equipment, system, or process is in its intended functional condition at a given time and therefore is either in use or capable of being used under a stated environment.

Availability (Equivalent)—The percentage of time in a period that gross maximum generation could be produced if limited only by outages and unit and seasonal deratings.

Availability (Operating)—The percentage of time in a period that the system, process, or facility is operating or is available to operate (ready status). This measure ignores partial outages, i.e., if the system is producing any product at all, it is considered to be "available."

Capacity—The net power output for which a generating unit or station is rated.

Capacity, Gross Maximum—The maximum capacity that a unit can produce over a specified period of time.

Capacity, Gross Dependable—The gross maximum capacity modified for ambient limitations for a specified period of time, such as a month or a season.

---

*Institute of Electrical and Electronic Engineers. 1979 (Jun.). Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity. Final Draft. Prepared by Power Plant Productivity Definitions Task Force, Application of Probability Methods Subcommittee, Power Systems Engineering Committee. New York.

Capacity, Gross Available—The gross dependable capacity modified for equipment limitation at any time.

Capacity Factor—A percentage calculated from the ratio of product actually produced in a period to the product that would be produced if the process system or facility operated at full rated capacity for the period.

Confidence Level—Statistical boundaries limiting an estimate with a specified risk.

Configuration Management—A technical and administrative process used to identify, control, and account for engineering documents describing the functional and physical characteristics of components, equipment, systems, or a process. It is also used to track and control hardware to conform to the documentation.

Corrective Maintenance—All unscheduled inspection, testing, or repair activities performed on equipment, following its failure, for the purpose of restoring the equipment to satisfactory operating condition.

Critical Item—A procedure, material, component, or item of equipment whose failure could significantly affect safety, performance, environment, schedule, or cost.

Debugging (Burn-In)—A process of shaking down each item of finished equipment that is performed prior to placing the item in use. During this debugging period, weak system elements are expected to fail and be replaced by elements of normal quality (statistically) that are not subject to similar early failure. The debugging process may involve exposure to all field operational stresses. The debugging process is not, however, intended to detect inherent weaknesses in system design, which should have been eliminated in the preproduction stages by appropriate techniques. The debugging process eliminates the parts subject to infant mortality.

Demonstration Plant—An RD&D project designed to demonstrate and validate economic, environmental, and productive capacity of a near-commercial size plant by integrating and operating a single modular unit using commercial-size components.

Derating, Seasonal—The difference between gross maximum capacity and gross dependable capacity.

Derating, Unit—The difference between gross dependable capacity and gross available capacity.

Design Life—The expected time or number of cycles, based on the design of the item, during which the item remains operationally effective and economically useful before wearing out.

Design Reviews—Meetings held during the design process to critically examine the product design, configuration, design documentation, test program planning, and test data.

Design Review, Critical (CDR)—A formal customer review of all accomplishments during detailed design. This may entail review of prereleased detailed design documentation; e.g., drawings and specifications, analytical and experimental verification data, long lead item procurement list, bid package plan, siting and environmental impacts, final test and evaluation plan, configuration, and change control procedures.

Design Review, Preliminary (PDR)—A formal customer review of process analyses and flow, reaction rates, operating parameters, including identified layout arrangement of equipment/systems, performance requirements, specifications of long lead items, and test plans.

Destructive Testing—Testing of any nature that may materially affect the life expectancy of the item tested, whether or not failures occur during the test.

Failure—The cessation of the ability of a system or any of its elements to perform a specified function or functions.

Failure Analysis—The study of a specific failure to determine the failure mode, mechanisms, and/or the circumstances that caused the failure.

Failure Effect—A description of the consequence of the failure in terms of operating or performance characteristics; e.g., shutdown, loss in efficiency, safety hazard.

Failure Mechanism—The physical process or occurrence that caused a failure (e.g., stress corrosion cracking, operator error, equipment malfunction, relay contacts welded by overload, and bearings frozen by contamination with foreign material).

Failure Mode—The observed local result of a failure; e.g., leak, loss of control, false output.

Failure Modes and Effects Analysis (FMEA)—Identification and documentation of each significant failure mode of each item and the impact of the occurrence of that mode of failure on the component, other components, and the overall operation of the system.

Failure (Noncurtailing)—A component failure that occurs with no effect on the output of the plant.

Failure Rate (Failures Per Unit of Time)—The number of failures per unit of time in a specified time interval.

Failure Reporting and Corrective Action—A systematic and comprehensive method of reporting failures and a means for implementing the corrective maintenance indicated by these failures.

Fault Tree Analysis—A method for relating a process or system failure to equipment, component, or materials failure modes using fault trees. A fault tree is a model that graphically and logically represents the various combinations of possible events, fault and normal, occurring in a process or system that leads to the top event. Process or system elements may include hardware, software, and human and environmental factors.

Forced Outage Rate—The ratio of forced outage hours to operating hours, plus forced outage hours.

Functional Configuration Audit—A formal examination of test data, prior to acceptance, to verify compliance of measured performance with specification requirements.

Functional Test—A test that directly or indirectly measures a specific function of equipment or a component.

Hazard—Any real or potential condition that can cause injury or death to personnel or damage to or loss of equipment or property.

Life-Cycle Cost Analysis—A function whose objective is to optimize the economics resulting from costs expended for design, construction, operation, and maintenance of equipment, a component, a system, or a process. LCC analyses are significant for:

- Assisting engineering in design trade-offs by providing a baseline of total life-cycle costs for all major design alternatives
- Providing a basis for determining the least cost involved in other major project alternatives (e.g., maintenance concept development, planning system operation and support activities, and maintenance planning).

Load Factor—The ratio of the actual energy supplied during a designated period to the energy that would have been supplied if the peak load were to exist throughout the designated period.

Loss-Of-Load Probability (LOLP)—The proportion of time that the generation available is unable to meet the system load (kilowatt). The loss-of-load probability is normally expressed in terms of days when the load is not met in the years studied (e.g., an LOLP of one day in 10 years means the load is not met one day in a period of 10 years.

Maintainability—A characteristic of design and installation that is expressed as the probability that an item can be restored to operation within a specified period of time when maintenance is performed in accordance with prescribed procedures and resources.

Maintenance—All actions necessary for retaining an item in a specified condition before failure or breakdown (preventive maintenance) or the process of restoring an item to return it to a workable condition (corrective maintenance).

Maintenance Concept—A description of the planned general scheme for maintenance and support covering replacement or repair philosophies, personnel factors, maintenance time, schedules, special tools, materials, supplies, spares, and other resources required to perform either corrective or preventive maintenance.

Maintenance Engineering Analyses—An analytical process in which the quantitative requirements, support resources, cost, operational objectives, and safety considerations that effect each preventive and anticipated corrective maintenance action are estimated and documented.

Mean Time Between Failures (MTBF)—Total operating time (frequently stated in hours) divided by the total number of failures.

Mean Time to Outage (MTTO)—Operating time divided by the number of outages experienced. This measure can be calculated for full, partial, or all outages (i.e., planned, forced) and is most applicable to mature technologies.

Mean Time To Restore (MTTR)—Average time to restore the system, process, or facility to full operability after an outage (full, partial, or all). This measure includes all maintenance and delay time encountered in restoring a system (e.g., waiting for parts). It can be used for identifying problems early in the maintenance program, the operational procedures, and the system design. It also includes time used for operator-initiated restoration activities (e.g., restart actions), which may restore the system in lieu of performing a maintenance action.

Mean Time To Repair (MTTR)—Average time to repair (or replace) a failed item during corrective maintenance. This measure excludes time waiting for parts, travel time, and other time not directly associated with the performance of the corrective maintenance activity. It can be used for identifying problems early in the maintenance program and/or system design characteristics affecting maintenance.

Mean Maintenance Man-Hours—Average total maintenance man-hours required to perform preventive maintenance (servicing) and corrective maintenance (repairs or replacements of failed items). This measure is important in evaluating required maintenance staffing and projecting future maintenance costs.

Nondestructive Testing—A test that is neither functional nor potentially destructive. It is performed to establish acceptability; e.g., X-ray analysis, leak tests, ultrasonic tests, etc.

On-Stream Time—The percentage of time in a period that the system, process, or facility is producing products equivalent to "operating availability."

Outage, Forced—The failure of a system resulting in loss of all or part of the output. A full outage results in complete loss of output; a partial outage results in degraded system output.

Outage, Planned—The period a unit is unavailable due to inspection, testing, nuclear refueling, or overhaul. A planned outage is scheduled well in advance and is of a predetermined duration.

Percentage Reserve—The margin of installed capacity in excess of the expected peak load.

Performance Assurance—A method for the systematic treatment of reliability, maintainability, availability, life-cycle cost, standardization, configuration management, and quality assurance in the design, construction, and operation of a system.

Performance Indices—Completely describe the performance of electrical-power operating unit. Included are capacity factor, availability (operating and equivalent), and outage rates (forced and planned).

Pilot Plant—An R&D project designed to establish integrated process feasibility by combining commercial type (not commercial size) components into a small model plant to test and evaluate the critical parameters of scale-up. It also is used to acquire engineering data needed to assess economic feasibility and design a larger near-commercial size plant.

Plant—The aggregate of major systems, personnel, procedures, and practices that perform the collective total functions of a process (e.g., coal liquefaction).

Plant Operability—The overall cost-effective plant generation needed to produce a required quantity of acceptable products at a predictable rate and at an acceptable level of reliability.

Preventive Maintenance—Actions performed in an attempt to keep an item in working condition and prevent failures or degradation of performance characteristics by planned (usually scheduled) servicing, replacement, overhaul, etc.

Quality Assurance—The system of engineering activities that assures quality by performing and preparing implementation documents for quality control. It includes analyzing all quality-related considerations for the development, implementation, and continuing evaluation of a quality control system.

Quality Control—The system of inspection and testing activities that are performed, documented, and used to measure, monitor, and control quality as well as to initiate corrective and/or preventive action in controlling selected characteristics of an item. It also performs the acceptance or rejection function at key points in the evolution and/or use of a product and implements the quality control system developed by quality assurance.

Redundancy—The existence of more than one means for accomplishing a given task, where all means must fail before there is an overall failure to the system.

Redundancy, Parallel—The existence of two systems working at the same time to accomplish the task, where either system can handle the job itself in case the other system fails.

Redundancy, Standby—The existence of an alternate means of accomplishing the task which is switched in by a malfunction sensing device when the primary system fails.

Reliability—The probability that an item or process performs its intended function for a specified time interval under a stated environment.

Reliability, Dynamic—The ability to withstand a sudden outage in its first few seconds or minutes without causing additional loss of facilities (i.e., preventing a cascading effect that may lead to widespread blackout).

Reliability, Inherent—The potential reliability present in an item's design.

Reliability, Operational—The assessed reliability of an item based on field data.

Reliability, Starting—The ratio of starting successes to total number of starting attempts.

Reliability, Steady-State—The system's ability to meet demand within specified voltage limits and the ratings of transmission lines during outages of some generating units and transmission lines.

Risk—The probability of occurrence of a specific deleterious consequence with a specific dimension; e.g., number of fatalities.

Security—System reliability in the steady-state and dynamic sense during actual operation, in contrast to its assessment (used by utility operating personnel).

Standard—A prescribed set of rules, conditions, or requirements established by standards setting bodies, concerning definition of terms, classification of components, specification of materials, performance or operations, delineation of procedures, or measurement of quantity and quality in describing materials, products, systems, services or practices.

Service Life—The period of time during which a material, component, equipment, system, or process is expected to perform in a satisfactory manner under specified operational conditions prior to wear out or obsolescence and consequent removal from service.

Subsystem—A combination of personnel, equipment, procedures, and practices that performs a subgroup of functions within a system (e.g., "carbon burn-up cell," "hot gas cyclone," and "coal preheater."

System (Major)—A combination of personnel, equipment, procedures, and practices which performs a distinct group of functions within the plant (e.g., "utilities system," "coal preparation," "fluidized bed combustion system," "gas cleanup system").

System Safety Engineering—The activities identified with the analysis of system design and operation for the timely identification and elimination of hazards. System safety activities closely parallel those of reliability to ensure that system safety is achieved early in the design phase and maintained throughout the system life cycle.

Trade-Off Analyses—Studies performed to optimize design in which interrelationships among performance, technical risk, cost, schedule, and safety are established and the effects of variations in these factors are determined.

Useful Life—The length of time an item operates with an acceptable failure rate.

APPENDIX B

DEPARTMENT OF ENERGY
FOSSIL ENERGY EQUIPMENT DATA SYSTEM (FEEDS)*

(Extracted from Procedures for the Operation and Use of the Fossil Energy Equipment Data System (FEEDS), System Development Corporation, March 1978)

The Fossil Energy Equipment Data System (FEEDS) is being established to provide for the collection, analysis, storage, and dissemination of equipment and material failure, availability, operability, and maintainability information generated through the operation of fossil energy plants. The FEEDS program will allow current and future plant designers, builders, operators, and managers access to detailed failure root causes, materials properties and reliability related information. This information will allow them to improve the quality of fossil energy plants by furnishing meaningful estimates of maintenance and operating costs of future developmental plants and commercial ventures and cost estimates that can determine the economic viability of these projects.

Selected DOE fossil energy contractors, typically involved in larger and longer-lived efforts such as pilot plants and demonstration plants, will be required to collect failure information. They will enter it on a Failure and Maintenance Report (FMR) form and forward it to the FEEDS Operations Office where it will be screened for completeness and analyzed for technical correctness. If deemed necessary, additional technical testing and analysis will be performed either at the National Bureau of Standards or at other national labs. The original FMR, along with any follow-up analysis will then be included in a special FEEDS module of the Government-Industry Data Exchange Program (GIDEP). This information will then be accessible to all FEEDS participants and other GIDEP members.

The overall system management will be provided by the DOE Performance Assurance System office. There are six agencies participating in the FEED system with defined responsibilities:

- Fossil energy contractors
- FEEDS Operations Office
- National Bureau of Standards (NBS)
- Government-Industry Data Exchange Program (GIDEP)
- DOE Fossil Energy Project Managers
- DOE FEEDS management (PAS Office).

The remainder of this appendix describes the responsibilities of these agencies and presents some of the guidelines used in preparing and processing the FMR form.

FOSSIL ENERGY CONTRACTORS

Fossil energy contractors selected to participate in the FEED Failure and Maintenance Reporting System typically will be those involved in larger or longer-lived projects. These will be chosen by DOE management using specific criteria involving dollar values of contracts, expected length of the effort, and the extent to which their experience will be valuable in other fossil energy efforts.

The basic task of the fossil energy contractor is to report significant failures. A failure may be defined as follows:

> The rendering of a piece of equipment, a component, or material incapable of performing its designed function through break, rupture, the binding of interfaces, etc.

The definition of a significant failure is not quite so straightforward and will be given more heuristically. A definition of a significant failure is as follows:

> A failure that affects the operation of the process being investigated and that might have a bearing on process upgrading to commercial size or that might affect the design, construction, or operation of other research, development, or demonstration plants.

Reportable failures, as defined above, are to be reported on the Failure and Maintenance Report Form (FMR) form (see Fig. B-1). Fossil energy contractors are to complete the form in the event of an equipment, component, or materials failure after the completion of corrective maintenance actions.

As shown in Fig. B-1 the FMR form provides for a complete description of the failure including date, time, condition, circumstances, causes as well as a description of the maintenance action taken including downtime and maintenance man-hours. DOE has developed descriptions, terms, and other guidelines that can help ensure uniform and consistent reporting and processing of failure and maintenance actions via the FMR form. Tables B-1 through B-4 present the terms used to describe failures (FMR, Item 9) causes (FMR, Item 10), effects (FMR, Item 13), and maintenance actions (FMR, Item 14). The terms listed are not exhaustive, but they are intended to serve as a guide in the reporting and analysis of failure and maintenance actions.

FEEDS OPERATIONS OFFICE

The FEEDS operations office is responsible for the administrative functions of FEEDS. It will conduct technical liaison with NBS and other national labs that will be doing research on failure base causes. The office will be responsible for communicating with fossil energy contractors by monitoring their reports, making follow-up contact as necessary, and providing them with reports on the status of all reported failures.

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

FAILURE – MAINTENANCE ACTION REPORT

1. Process/Project	2. Contract Number
3. Contractor (Name and Address)	4. Report Number
	5. Date of Failure / 6. Time of Failure
7. Description of Failed Component	
8. Component Environment (Temperature, Working Material, Composition, Velocity, Pressure, Loads, Etc. – Note Whether Nominal or Observed)	
9. Description of Failure (When/How Discovered, Primary or Secondary Failure)	
10. Cause of Failure	
11. Any Previous Repairs? If So, When?	
12. Operating Time of Component	
13. Effect on System/Plant	
14. Maintenance Action Taken	
15. Maintenance Duration (Clock Hours, Tenths of Hours)	16. Maintenance Man hours Required
17. Disposition of Failed Component	
18. Remarks and/or Recommendations:	
19. Name of Preparer and Date:	20. Telephone Number

Figure B-1. FEEDS Failure and Maintenance Report Form

Table B-1. FAILURE MODE AND MECHANISM TERMS (FMR, Item 9)

leak	spurious operation
crack	false response
break	false output
physical distortion	no response
collapse	no output
fracture	insufficient processing
break	insufficient transmission
won't start	nontransmission
won't open	degraded output
won't stop	inverse operation
won't close	erratic operation
won't hold	vibration
won't release	pulsation
out of operating limits	frozen
out of adjustment	melted

Table B-2. FAILURE CAUSES (FMR, Item 10)

corrosion	operational accident
aqueous corrosion	quality control
sulfidation	residual stresses
oxidation	stress corrosion cracking (SCC)
carburization	stress corrosion cracking chloride (SCC-CC)
metal dusting	stress relaxation
design	thermal cycling
equipment	thermal shock
equipment maintenance	thermal stress
equipment malfunction	overheating
equipment misuse	pitting
operator error	abnormal service conditions
overstressing	manufacturing defect
erosion	installation error
fabrication	construction error
welding	testing error
fatigue	maintenance error
mechanical shock	natural end of life
fire	associated devices

Table B-3. FAILURE EFFECTS (FMR, Item 13)

shutdown	safety hazard
degraded operation	unscheduled maintenance
loss of redundancy	delayed startup
process upset	switch to backup
plug	
reduction of capacity	
no significant effect	
reduction in efficiency	

Table B-4. MAINTENANCE ACTIONS (FMR, Item 14)

repair in place
remove and replace
replace parts or subassemblies
save part
discard part
no malfunction found

The office will also be responsible for adding the report number to the FMR and for some additional information (such as component description, environment, name of preparer, and date) on a coding sheet (see Fig. B-2).

The additional coding sheet is completed by extracting the required information from the FMR (or by direct contact with the originator, if necessary). The coding sheet is attached to the original FMR for forwarding to GIDEP.

The component description subfields are coded based on the information entered in Description of Failed Component entry on the FMR form. The appropriate component name either is chosen from a predetermined component name vocabulary (see Table B-5) or selected by the FEEDS office if no appropriate name is listed. Table B-5 presents a partial listing of fossil energy components to illustrate the detail of hardware classification. As additional component names appear, revisions will be compiled and distributed to users by the FEEDS operations office. Also, the construction material of the failed component is to be entered, if known. Table B-6 presents a partial list of construction materials found in fossil energy literature and used in the NBS Failure Prevention Information Center that illustrates the detail of material classification.

To more fully describe the environment in which the component failed, two additional environment subfields will be determined by the FEEDS operations office and entered in the coding sheet. These are two digit numeric fields describing the temperature (−460° to 5000° F) and pressure (high vacuum to 6000 psi) environment of the failed component as shown in Fig. B-2.

Table B-5. VOCABULARY OF FOSSIL ENERGY COMPONENTS (Partial Listing)

(a) General Process

- auxiliary process equipment
- compressors
- blowers
- heaters
- fans
- motors
- seals
- switches
- transformers
- coils
- filters
- towers
- feeders

(b) Coal Liquefaction

- decanter
- autoclave
- pyrolyzer
- hydrotreater
- pulverizer
- reactor
- batch feeder
- condenser
- separator
- fire prevention system
- ventilation system
- catalyst
- vaporizer

(c) Coal Gasification

- lockhopper
- absorber
- producer
- gas preheater
- ash hopper
- stretford unit
- fixed-bed gasifier
- girate drive system
- stirrer
- hydrogen plant
- gas generator
- gasifier
- regenerator
- methanator
- engager pot
- elevator
- scrubber
- dowtherm tank
- thermal oxidizer
- receiver

(d) Coal Power & Combustion

- fluidized bed combustor
- hopper
- bag filler
- plenum
- air injector
- inverted conical air distributor
- screw feeder
- baghouse
- deaerator
- velocity
- monitor
- heat exchanger
- ball mill
- char pre-heater
- dust hopper
- flow reactor
- oil storage
- tank

(e) Fossil Demonstration Plants

- fractionator
- steam generator
- gas cooler
- condensator
- aromatic condenser
- cold box
- methanator
- dryer, gas, fluidized coal
- still, atmospheric, vacuum
- sulfur recovery unit
- cryogenic separator

(f) Magnetohydrodynamics

- seed tank
- LN_2 storage
- LO_2 storage
- combustor
- MHD generator (linear, disk)
- magnet
- magnet power supply
- conductivity channel
- quench system
- radiant boiler
- peg brick

REPORT NUMBER ____________

COMPONENT DESCRIPTION ____________

COMPONENT-NAME ____________
COMPONENT-NUMBER ____________
MATERIAL ____________
MANUFACTURER ____________

ENVIRONMENT

TEMP
PRESS

PREPARATION-DATE

Figure B-2. FEEDS Operations Office Additional Coding Sheet

The FEEDS operations office also is responsible for a substantial amount of reporting with three major responsibilities.

- FMR Status Reports. Each month, the FEEDS operations office will provide a report indicating the status of all FMRs. This will include a brief abstract of each failure reported, the source of the report, and the status of any further investigation arising from the report. This FMR status report will be sent to all participating contractors, DOE management, and appropriate members of NBS.
- Quarterly Status Reports. These will be sent to the DOE PAS office, the agency managing FEEDS, which will route them to appropriate agencies within DOE. These reports basically will be summaries of the activities of FEEDS and includes statistical data on the numbers of FMRs processed, proposed, or actual changes to the search system, and management and financial status reports. Data on the usage of FEEDS will also be included.
- GIDEP Quarterly Progress Reports. As a condition for membership in the GIDEP System, GIDEP requires a quarterly progress report showing data summaries, data utilization, and costs avoided through use of the system. This report will be submitted on a form provided by GIDEP and should include generally the same information as the quarterly status report to DOE.

Table B-6. MATERIALS OF CONSTRUCTION

alonized metals	stellite
cast iron	supertherm
ceramics	7079-T651 aluminum
copper	30/70 tin-lead solder
Hastelloy Y	50/50 tin-lead solder
HD-40	95/5 tin antimony
Inconel 600, 601, 617, 702	MgO cored and checker brick
Incoloy 800	high purity and density magnesia
Incoloy 825	alumina and zirconia tubes
Kennametal 701	zirconia-alumina-silicate materials
refractory	Al_2O_3 - Cr_2O_3
stainless steel 304, 310, 316 321, 321H, 330, 347, 440C 446	Al_2O_3 - Fe_2O_3 - Cr_2O_3
steel	SiC
carbon steel	ZrB_2 - SiC
cast steel	

In addition to the major coding and reporting responsibility of the FEEDS operations office, several additional duties are required. Its responsibilities are to:

- Participate in evaluating failure root causes by obtaining additional technical expertise as required from NBS or other laboratories
- Forward FMRs to GIDEP for inclusion in the fossil energy module of the data bank
- Copy all FMRs submitted and additional coding forms completed and maintain a file of the copies
- Maintain an FMR log showing the status of all FMRs
- Maintain liaison with selected fossil energy contractors to ensure complete failure reporting
- Receive reports from GIDEP and circulate them to participants
- Act as formal GIDEP representative and comply with their reporting requirements
- Prepare and circulate quarterly summary reports to DOE management and FEEDS participants on status and usage of FEEDS
- Act as training liaison for participants wishing to use the FEEDS/GIDEP retrieval system
- Act as liaison with GIDEP to incorporate any changes or improvements in the GIDEP retrieval system
- Incorporate improvements/additions to the FEEDS program as they are developed
- Coordinate expansion of the FEEDS program to include operability and availability data

- Provide occasional searches of GIDEP data banks for FEEDS participants
- Periodically update the FEEDS search methods and vocabulary as experience with the data warrants
- Coordinate with DOE project managers to ensure contractor compliance with reporting requirements.

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards will act as the chief technical arm of FEEDS using its expertise in materials and failure analysis. Its responsibilities are to:

- Provide a member to the FEEDS office who will be responsible for technical evaluation of the failure and maintenance reports
- Provide office space and administrative support to the FEEDS operation office
- Make available personnel for technical consultation on failure root causes
- Recommend appropriate laboratories for the performance of additional testing and analysis on failure components as required
- Provide access to the NBS Materials Failure Prevention Data Center.

GOVERNMENT-INDUSTRY DATA EXCHANGE PROGRAM

The Government-Industry Data Exchange Program (GIDEP) is the data entry, computer and microfilm storage, and information retrieval arm of FEEDS. It is located at the Fleet Analysis Center in Corona, Calif., and currently provides access to general engineering, metrology, reliability and maintainability, and failure data to about 450 participants. GIDEP will establish and maintain a fossil energy module to accommodate FEEDS.

Specific responsibilities of GIDEP are to:

- Receive failure and maintenance reports from the FEEDS operations office
- Enter FMRs into the FEEDS module of the GIDEP data bank
- Conduct training and other liaison with the FEEDs operations office as required
- Provide its regular reports to the FEEDS operations office and to other FEEDS members who become members of GIDEP
- Encourage use of the FEEDS data base by other GIDEP users
- Provide the FEEDS office information on the utilization of the fossil energy module of GIDEP
- Implement modification of the FEEDS search vocabulary as specified by the FEEDS operations office.

DOE FOSSIL ENERGY PROJECT MANAGERS

The DOE project managers are the vehicle through which FEEDS is to be implemented. They require contractor participation in the system. They will receive the monthly and quarterly reports generated by the FEEDS office.

Their specific responsibilities are to:

- Issue directives to contractors to fulfill their responsibilities within FEEDS
- Include a requirement for failure and maintenance reporting in new contracts with appropriate contractors.

DEPARTMENT OF ENERGY FEEDS MANAGEMENT

The DOE Performance Assurance System (PAS) office is the primary management and control arm of FEEDS. The PAS office will coordinate direction of the FEEDS program with the Materials and Exploratory Research Division of DOE fossil energy. FEEDS overall direction and major changes in approach, emphasis, or method will originate with DOE management.

Specific responsibilities are to:

- Provide direction and coordinate funding for FEEDS
- Encourage contractor participants to fulfill FEEDS requirements
- Contract for expansion of the system to include operability and availability data
- Give final approval to all reports, forms, etc.
- Maintain a computer terminal and microfilm reader/printer for access to GIDEP, and illustrate the FEEDS program to those interested.

APPENDIX C

BONNEVILLE POWER ADMINISTRATION (BPA) QUALITY PROGRAM REQUIREMENTS AND SURVEY REPORT

SERI

BONNEVILLE POWER ADMINISTRATION (BPA)

SPECIFICATION

QUALITY PROGRAM REQUIREMENTS

4-1 GENERAL

4-1.1 SCOPE. This specification establishes requirements for a quality program which shall be developed and maintained by the contractor to assure that materials, products, and service are in compliance with the requirements of related contracts.

4-1.2 CONTRACTUAL INTENT. The extent and complexity of the contractor's program, as required to meet the requirements of this specification, shall depend on the products involved, the technical aspects of manufacture, the degree of subcontracting, and the contractor's facility and organization. BPA Quality Program Reviews will be based on these factors and conditions.

*4-1.3 QUALITY PROGRAM REVIEWS. The contractor's program shall be subject to review by BPA until it meets the requirements herein and has been approved. Thereafter, the quality program shall be subject to resurvey on a 2- to 3-year basis or at any time the quality program is not accomplishing its objectives. Quality surveys and quality program surveillance will be conducted by the BPA Quality Assurance Officer.

If the contractor's quality program has not been previously approved by BPA, the contractor should submit his quality program manual to the BPA Quality Assurance Officer for review within 45 days after contract award. If need be, special arrangements can be made for BPA to review the manual at the contractor's facilities. After the manual review, BPA will conduct a physical survey for implementation of the quality program. The contractor's quality program will be approved upon satisfactory demonstration that it meets the requirements herein.

The contractor's quality program is subject to disapproval by the Contracting Officer whenever the contractor's program does not accomplish its objectives.

4-2 COORDINATION WITH BPA ENGINEERING REPRESENTATIVE

*4-2.1 The contractor's quality program shall allow for coordination with the control actions of the BPA Engineering Representative (ER) as outlined in BPA Specification EMQ 1.1 CONTRACT MANAGEMENT PROVISIONS, however, performance of these control actions by the BPA ER does not relieve the contractor of his quality responsibility.

*4-2.2 The BPA ER shall have access to the contractor's drawings, specifications, records, purchase orders, and other documents as required to accomplish these control actions.

*4-2.3 After any design or qualification test has been approved (effective point), significant changes shall not be made in design or manufacture without approval by the BPA ER.

*4-2.4 Inspection and test plans shall be submitted to the BPA ER for review and comments. The plan is subject to disapproval by the BPA ER when it is not adequate to accomplish its objectives. Objective evidence of inspections and tests made to this plan shall be readily available to the BPA ER prior to the BPA factory release of material or equipment.

4-3 DOCUMENTATION

4-3.1 The contractor shall establish and maintain written procedures defining his quality program. The contractor's written documentation shall include, but not be limited to, the requirements of this specification.

4-3.2 The term "quality manual" shall be understood to refer to this written documentation, but it is also understood that the documentation may be distributed throughout the contractor's organization in the form of manuals, procedures, etc., which is acceptable as long as a primary document, which is traceable to secondary level documents, is maintained.

4-4 QUALITY PROGRAM MANAGEMENT

4-4.1 To assure timely and effective management, the program shall:

a. Make functional assignments to implement each element of the total program. Personnel performing quality program functions shall have sufficient, well-defined responsibility, together with adequate authority and organizational freedom to fulfill the responsibility.

b. Provide for the necessary training for all personnel who are involved in the quality program.

c. Provide for internal audits of all procedures and operations to compare actual operations with established requirements and to develop necessary recommendations.

d. Provide for quality cost reporting including scrap and rework costs, field failure and warranty costs, inspection and test costs, and prevention costs.

e. Provide for periodic management reviews of the status and effectiveness of the total program.

4-4.2 To assure timely and effective processing of the customer's order, the program shall:

a. Provide for initial review of the order to identify and plan for any special design, manufacturing, testing, shipping, or other requirements, as applicable.

b. Provide for clearly defined channel of communication, both internal and external.

c. Provide for effective planning and scheduling of submittal of required technical documentation.

d. Provide for design review to ensure that customer requirements are fully included and to ensure that the overall quality of design is maintained.

4-5 DRAWINGS, SPECIFICATIONS, AND CHANGES

4-5.1 Technical documents, such as product and material specifications, drawings, work instructions, route sheets and assembly and process specifications shall include, as applicable, the following information:

* Revisions since September 15, 1975 issue are marked by asterisks.

a. Characteristics and design criteria necessary for procurement, fabrication, assembly, inspection, and test operations.

b. Characteristic tolerance for all dimensions, process variables, or measured attributes specified in the technical documents.

c. Identification to which procurement, fabrication, processing, inspection and test can be related, i.e., unique part or piece mark number.

4-5.2 The contractor shall maintain a change control system for all technical documents, which shall:

a. Ensure that only current documents shall be available to operating personnel.

b. Provide for initiation of documented change requests and resulting decisions.

c. Provide for review procedures to ensure that proposed changes will not adversely affect quality, reliability, or compliance with contract requirements.

d. Provide a system for implementing and recording product revisions at effective points.

4-5.3 The contractor's quality personnel shall participate in design reviews to insure that designs permit and facilitate producibility, interchangeability and inspectability, and that other related quality considerations are obtained. Quality personnel shall conduct timely reviews of technical documents and associated changes to insure that all necessary information has been included and that the requirements are clear.

4-5.4 Adequate provisions shall be made to assure that all necessary customer specifications, drawings, and quality provisions are readily available to the contractor's engineering, production, and quality personnel.

4-6 CONTROL OF PURCHASES

4-6.1 The contractor is responsible for assuring that all supplies and services conform to contract requirements. This responsibility includes:

a. The selection of qualified suppliers.

b. The transmission of all technical and quality requirements to suppliers.

c. The evaluation of procured articles against order requirements.

d. A system to assure and record action to correct and prevent recurrence of discrepancies found in contractor purchased items.

e. Providing technical assistance and training to suppliers when necessary to achieve required quality levels.

4-6.2 The contractor's quality control organization shall have the authority to disapprove the use of suppliers who do not have a quality system to meet the procurement requirements.

4-6.3 Objective evidence shall be kept on file to show that all materials, articles, and processing received by the contractor for subsequent incorporation into end products meets the customer order requirements.

4-6.4 When BPA witness is required by the contract Assurance Inspection Requirements (AIR), the purchase order shall:

a. State that BPA witness is required.

*b. Supply name and address of the BPA ER.

*c. Instruct the suppliers to coordinate the BPA ER control actions through the contractor's organization.

4-6.5 Investigations by BPA at the supplier's plant will be performed with the knowledge of the contractor. When BPA elects to perform inspection at a supplier's plant, such inspection shall not be used by the contractor as evidence of effective control of quality by his suppliers.

4-7 RECEIVING INSPECTION

4-7.1 The contractor's receiving inspection system shall include the following:

a. Written instructions for the inspection, sampling plan, and acceptance criteria of all purchased supplies.

b. Records of tests, inspections, and certifications on purchased supplies.

c. Methods for identifying, handling, and storing incoming supplies.

d. Methods for segregation of nonconforming supplies to prevent their use.

4-8 PROCESSING AND FABRICATION CONTROL

4-8.1 FABRICATION CONTROLS. The contractor shall control his work operations including machining, fabricating, and assembling to ensure that specified characteristics are obtained and maintained. Detailed fabrication documents shall be prepared for use by production personnel conducting such operations and shall include:

a. Identification of the article.

b. Tooling, jigs, fixtures, numerical tapes, and/or other equipment.

c. Characteristics and allowable tolerances.

d. Detailed work instructions for controlling operations.

e. Special precautions.

f. Workmanship standards.

4-8.2 PROCESS CONTROLS. The contractor shall implement process controls to assure uniform quality. Such processes include welding, heat treating, curing, impregnation, drying, plating, painting, and surface treatment.

In addition, nondestructive testing processes such as radiographics, ultrasonics, dye penetrant, and magnetic particle shall be controlled to ensure adequate indication of the product or material quality levels. Process procedures shall describe:

a. Application of the process.

b. Preparation of the articles or materials.

c. Detailed instructions.

d. Factors and conditions to be maintained during each step.

e. Methods of verifying the adequacy of ingredients, solutions, equipment, environmental conditions, their related tolerances, and frequency of checks.

f. Records for documenting the routine controls.

4-8.3 CERTIFICATIONS. The contractor shall provide for the certifications of personnel, equipment, and process procedures requiring submittal by the contract. Certifying records shall be maintained.

4-8.4 WORKMANSHIP STANDARDS. General Workmanship standards shall be an integral part of the contractor's quality program.

4-8.5 PROCESS AND FABRICATION AUDIT. The contractor's quality program shall include planned periodic audits to assure compliance with all process and fabrication documentation.

4-9 TOOLING

4-9.1 The contractor shall verify tooling by means of periodic inspections to verify their continued accuracy in use, and the results shall be recorded.

4-9.2 When production jigs, fixtures, templates, patterns, and such other devices are used in inspection, their accuracy shall be checked at periodic intervals, and the results shall be recorded.

4-10 MATERIAL IDENTIFICATION AND STATUS

4-10.1 The Quality Program shall provide procedures for identification of product, process, inspection, and test status throughout all phases of manufacture and storage.

4-11 SHIPMENT AND STORAGE

4-11.1 The contractor's quality program shall provide procedures for control of quality during storage and shipment in order to prevent damage, loss, or deterioration. Such procedures will specify the methods, materials, documentation, and special customer requirements required for handling, storing, preserving, packaging, packing, marking, customer releasing, and shipment.

4-12 MEASURING AND TEST EQUIPMENT

4-12.1 The contractor's quality program procedures shall identify the organization responsible for maintaining and calibrating measuring and test equipment.

4-12.2 All measuring and test equipment shall be maintained and calibrated prior to initial use and at periodic intervals. Records and controls shall be established to insure that this function is performed on schedule. Review procedures shall be established to adjust the frequency of maintenance and calibration as required to maintain continued accuracy at all times.

4-12.3 All test and measurement equipment shall be periodically calibrated against a standard of greater accuracy and a known relationship to U.S. National Standards or other basic standards.

4-12.4 The contractor shall maintain individual records of measurement standards and equipment. These records shall include identification of equipment to be calibrated, identification of calibration procedures, calibration intervals, dates, and results of each calibration, due date of next calibration, individual performing calibration, and calibration facility. In addition the condition and accuracy of the equipment received for recalibration shall be recorded.

4-12.5 All measurement standards and equipment shall be uniquely identified and be labeled, tagged, or coded to indicate calibration status and due date of next calibration.

4-13 INSPECTION AND TEST REQUIREMENTS

4-13.1 GENERAL. The contractor shall plan and conduct an inspection and test program which demonstrates that contract, drawing, specification, and quality provisions are met.

4-13.2 INSPECTION AND TEST PLANNING. Such planning shall encompass all areas of production including materials, components, subassemblies, end items, and preparation for delivery. Inspection and test plans shall include:

a. Production flow and inspection stations beginning with receiving inspection.

b. Characteristics to be inspected.

c. Cross-reference to detailed inspection and test procedures.

d. Sampling Plan.

e. Coordination of inspection and tests to be witnessed by the customer.

f. Data to be submitted to customer.

g. Nonconformance instructions.

4-13.3 INSPECTION AND TEST PROCEDURES. Written procedures shall be prepared for each inspection and test operation. They shall be readily available to inspection and test personnel at the applicable inspection station at the time of inspection and test. Each procedure shall include, as applicable:

a. Identification of the article or material.

b. Sampling plan or quantity to be tested or inspected.

c. Detailed sequential instructions.

d. Measurement characteristics and required measuring equipment.

e. Acceptable tolerances, with reference to specifications or drawings.

f. Acceptance and rejection criteria.

g. Allowable adjustment, repair, or rework.

h. Requirements for data recording and reporting.

i. Disposition of article or material.

4-14 QUALITY RECORDS AND INFORMATION FEEDBACK

4-14.1 The contractor shall generate and maintain records of all incoming, in-process, and final inspection and test data. These records shall indicate item identification, the actual measurement or test result, amount inspected or tested, amount acceptable, amount rejected, number and type of deficiencies, lot size, disposition, operator identification and date.

4-14.2 The contractor shall generate and maintain records to objectively document quality program activities. Such records include engineering changes, corrective actions, internal audits, calibration records, field reports, customer survey, and quality cost data.

4-14.3 Record retention policy shall be established for each type of record and its location. Records of inspection and tests performed on BPA contracts shall be maintained for a period of at least 3 years from the time of final delivery.

4-14.4 The quality program shall provide for the summary, analysis, and use of quality records as a basis for management action in each element of the quality program.

4-15 NONCONFORMING MATERIAL

4-15.1 The contractor shall establish and maintain an effective system for controlling nonconforming material, including procedures for its identification, segregation, and disposition.

4-15.2 The contractor shall prepare and issue documents for each nonconformance containing as a minimum:

a. A Serial Number.

b. Identification of the nonconforming material.

c. A description of the nonconformance, characteristic requirement, and tolerance.

d. Function responsible for the nonconformance.

e. Disposition of the nonconforming material: Scrap, rework, or repair, return to supplier, or submit to internal material review.

f. Method of rework or repair.

g. Reinspection and test method and results.

h. Dates and signatures of authorized personnel.

i. Identification of repeat nonconformance.

j. Establish need and responsibility for corrective action to prevent recurrence of the nonconformance.

4-15.3 The contractor shall maintain the records of all nonconformance for trend detection, cause analysis, and corrective action.

4-16 CORRECTIVE ACTION

4-16.1 The contractor shall establish and maintain a corrective action system to promptly detect and correct assignable conditions adverse to quality. Corrective action shall cover all areas of contractor operations and extend to all suppliers and deficiencies reported by users.

4-16.2 Each corrective action shall be executed according to the steps of the following closed loop with the results of actions compiled on a separate document for this purpose:

a. Notification of function responsible for deficiency.

b. Determine extent and causes.

c. Establish preventive actions.

d. Rework of existing product in all conditions of completion.

e. Followup to assure completion of corrective action.

f. Review of effectiveness.

QUALITY PROGRAM

BPA Specification
EMJ–1.3B

UNITED STATES DEPARTMENT OF ENERGY
BPA
BONNEVILLE POWER ADMINISTRATION

QUALITY ASSURANCE SURVEY REPORT

SURVEYED BY	REQUESTED BY	REASON FOR SURVEY

SUPPLIER NAME	PLANT	PHONE

STREET ADDRESS	CITY, STATE AND ZIP CODE

PERSONS CONTACTED

NAME TITLE	1 ______	2 ______	3 ______
NAME TITLE	4 ______	5 ______	6 ______

SUMMARY
CONTRACTOR EVALUATION PROFILE

ELEMENT	Work Required		Acceptable	
	Void	Incomplete	Adequate	Outstanding
Coordination				
Documentation				
Quality Program Management				
Drawings, Specifications, & Change				
Control of Purchases				
Receiving Inspection				
Fabrication Control				
Process Control				
Tooling				
Material Identification and Status				
Shipment & Storage				
Measuring and Test Equipment				
Inspection and Test Planning				
Inspection and Test Procedures				
Records and Information Feedback				
Nonconforming Material				
Corrective Action				

Outstanding – The contractor's operation and documentation exceeds BPA requirements and the performance continuously meets the contractor requirements.

Adequate – The contractor's operation and documentation meets BPA requirements and the performance continuously meets the contractor requirements.

Incomplete – The contractor's operation OR documentation (not both) are incomeplete. Contractor action required.

Void – No evidence of operation or documentation

SURVEY REPRESENTATIVE SIGNATURE DATE

SUPPLIER ACKNOWLEDGMENT SIGNATURE DATE

BPA 1235 F... 197.

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUTSTND
4-2 COORDINATION WITH BPA QUALITY CONTROL REPRESENTATIVE 4-2.1 The contractor's quality program shall allow for coordination with the control actions of the BPA QCR as outlined in BPA Specification EMJ 1.1 CONTRACT MANAGEMENT PROVISIONS, however, performance of these control actions by the BPA QCR does not relieve the contractor of his quality responsibility.					
*4-2.2 The BPA QCR shall have access to the contractor's drawings, specifications, records, purchase orders, and other documents as required to accomplish these control actions.					
*4-2.3 After any design or qualification test has been approved (effective point), significant changes shall not be made in design or manufacture without approval by the BPA QCR.					
*4-2.4 Inspection and test plans shall be submitted to the BPA QCR for review and comments. The plan is subject to disapproval by the BPA QCR when it is not adequate to accomplish its objectives. Objective evidence of inspections and tests made to this plan shall be readily available to the BPA QCR prior to the BPA factory release of material or equipment.					
4-3 DOCUMENTATION *4-3.1 The contractor shall establish and maintain written procedures defining his quality program. The contractor's written documentation shall include, but not be limited to, the requirement of this specification.					
*4-3.2 The term "quality manual" shall be understood to refer to this written documentation, but it is also understood that the documentation may be distributed throughout the contractor's organization in the form of manuals, procedures, etc., which is acceptable as long as a primary document, which is traceable to secondary level documents, is maintained.					
4-4 QUALITY PROGRAM MANAGEMENT *4-4.1 To assure timely and effective management, the program shall. a. Make functional assignments to implement each element of the total program. Personnel performing quality program functions shall have sufficient, well-defined responsibility, together with adequate authority and organizational freedom to fulfill the responsibility.					
b. Provide for the necessary training for all personnel who are involved in the quality program.					
c. Provide for internal audits of all procedures and operations to compare actual operations with established requirements and to develop necessary recommendations.					
d. Provide for quality cost reporting including scrap and rework costs, field failure and warranty costs, inspection and test costs, and prevention costs.					
e. Provide for periodic management reviews of the status and effectiveness of the total program.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STND
*4-4.2 To assure timely and effective processing of the customer's order, the program shall: a. Provide for initial review of the order to identify and plan for any special design, manufacturing, testing, shipping, or other requirements, as applicable.					
b. Provide for clearly defined channel of communication, both internal and external.					
c. Provide for effective planning and scheduling of submittal of required technical documentation.					
d. Provide for design review to ensure that customer requirements are fully included and to ensure that the overall quality of design is maintained.					
4-5 DRAWINGS, SPECIFICATIONS, AND CHANGES *4-5.1 Technical documents, such as product and material specifications, drawings, work instructions, route sheets and assembly and process specifications shall include, as applicable, the following information: a. Characteristics and design criteria necessary for procurement, fabrication, assembly, inspection, and test operations.					
b. Characteristic tolerance for all dimensions, process variables, or measured attributes specified in the technical documents.					
c. Identification to which procurement, fabrication, processing, inspection and test can be related, i.e., unique part or piece mark number.					
*4-5.2 The contractor shall maintain a change control system for all technical documents, which shall: a. Ensure that only current documents shall be available to operating personnel.					
b. Provide for initiation of documented change requests and resulting decisions.					
c. Provide for review procedures to ensure that proposed changes will not adversely affect quality, reliability, or compliance with contract requirements.					
d. Provide a system for implementing and recording product revisions at effective points.					
*4-5.3 The contractor's quality personnel shall participate in design reviews to insure that designs permit and facilitate producibility, interchangeability and inspectability, and that other related quality considerations are obtained. Quality personnel shall conduct timely reviews of technical documents and associated changes to insure that all necessary information has been included and that the requirements are clear.					
*4-5.4 Adequate provisions shall be made to assure that all necessary customer specifications, drawings, and quality provisions are readily available to the contractor's engineering, production, and quality personnel.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STND
4-6 CONTROL OF PURCHASES 4-6.1 The contractor is responsible for assuring that all supplies and services conform to contract requirements. This responsibility includes: a. The selection of qualified suppliers.					
b. The transmission of all technical and quality requirements to suppliers.					
c. The evaluation of procured articles against order requirements.					
d. A system to assure and record action to correct and prevent recurrence of discrepancies found in contractor purchased items.					
e. Providing technical assistance and training to suppliers when necessary to achieve required quality levels.					
4-6.2 The contractor's quality control organization shall have the authority to disapprove the use of suppliers who do not have a quality system to meet the procurement requirements.					
4-6.3 Objective evidence shall be kept on file to show that all materials, articles, and processing received by the contractor for subsequent incorporation into end products meets the customer order requirements.					
4-6.4 When BPA witness is required by the contract Assurance Inspection Requirements (AIR), the purchase order shall: a. State that BPA witness is required.					
b. Supply name and address of the BPA QCR.					
*c. Instruct the suppliers to coordinate the BPA QCR control actions through the contractor's organization.					
4-6.5 Investigations by BPA at the supplier's plant will be performed with the knowledge of the contractor. When BPA elects to perform inspection at a supplier's plant, such inspection shall not be used by the contractor as evidence of effective control of quality by his suppliers.					
4-7 RECEIVING INSPECTION 4-7.1 The contractor's receiving inspection system shall include the following: *a. Written instructions for the inspection, sampling plan, and acceptance criteria of all purchased supplies.					
b. Records of tests, inspections, and certifications on purchased supplies.					
c. Methods for identifying, handling, and storing incoming supplies.					
d. Methods for segregation of nonconforming supplies to prevent their use.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STND
4-8 PROCESSING AND FABRICATION CONTROL *4-8.1 FABRICATION CONTROLS. The contractor shall control his work operations including machining, fabricating, and assembling to ensure that specified characteristics are obtained and maintained. Detailed fabrication documents shall be prepared for us by production personnel conducting such operations and shall include: a. Identification of the article.					
b. Tooling, jigs, fixtures, numerical tapes, and/or other equipment.					
c. Characteristics and allowable tolerances.					
d. Detailed work instructions for controlling operations.					
e. Special precautions.					
f. Workmanship standards.					
*4-8.2 PROCESS CONTROLS The contractor shall implement process controls to assure uniform quality. Such processes include welding, heat treating, curing, impregnation, drying, plating, painting, and surface treatment. In addition, nondestructive testing processes such as radiographics, ultrasonics, dye penetrant, and magnetic particle shall be controlled to ensure adequate indication of the product or material quality levels. Process procedures shall describe: a. Application of the process.					
b. Preparation of the articles or materials.					
c. Detailed instructions.					
d. Factors and conditions to be maintained during each step.					
e. Methods of verifying the adequacy of ingredients, solutions, equipment, environmental conditions, their related tolerances, and frequency of checks.					
f. Records for documenting the routine controls.					
*4-8.3 CERTIFICATIONS. The contractor shall provide for the certifications of personnel, equipment, and process procedures requiring submittal by the contract. Certifying records shall be maintained.					
*4-8.4 WORKMANSHIP STANDARDS. General Workmanship standards shall be an integral part of the contractor's quality program.					
*4-8.5 PROCESS AND FABRICATION AUDIT. The contractor's quality program shall include planned periodic audits to assure compliance with all process and fabrication documentation.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STNC
4-9 TOOLING 4-9.1 The contractor shall verify tooling by means of periodic inspections to verify their continued accuracy in use, and the results shall be recorded.					
4-9.2 When production jigs, fixtures, templates, patterns, and such other devices are used in inspection, their accuracy shall be checked at periodic intervals, and the results shall be recorded.					
4-10 MATERIAL IDENTIFICATION AND STATUS *4-10.1 The Quality Program shall provide procedures for identification of product, process, inspection, and test status throughout all phases of manufacture and storage.					
4-11 SHIPMENT AND STORAGE *4-11.1 The contractor's quality program shall provide procedures for control of quality during storage and shipment in order to prevent damage, loss, or deterioration. Such procedures will specify the methods, materials, documentation, and special customer requirements required for handling, storing, preserving, packaging, packing, marking, customer releasing, and shipment.					
4-12 MEASURING AND TEST EQUIPMENT *4-12.1 The contractor's quality program procedures shall identify the organization responsible for maintaining and calibrating measuring and test equipment.					
4-12.2 All measuring and test equipment shall be maintained and calibrated prior to initial use and at periodic intervals. Records and controls shall be established to insure that this function is performed on schedule. Review procedures shall be established to adjust the frequency of maintenance and calibration as required to maintain continued accuracy at all times.					
4-12.3 All test and measurement equipment shall be periodically calibrated against a standard of greater accuracy and a known relationship to U.S. National Standards or other basic standards.					
*4-12.4 The contractor shall maintain individual records of measurement standards and equipment. These records shall include identification of equipment to be calibrated, identification of calibration procedures, calibration intervals, dates, and results of each calibration, due date of next calibration, individual performing calibration, and calibration facility. In addition the condition and accuracy of the equipment received for recalibration shall be recorded.					
*4-12.5 All measurement standards and equipment shall be uniquely identified and be labeled, tagged, or coded to indicate calibration status and due date of next calibration.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STND
4-13 INSPECTION AND TEST REQUIREMENTS *4-13.1 GENERAL. The contractor shall plan and conduct an inspection and test program which demonstrates that contract, drawing, specification, and quality provisions are met.					
*4-13.2 INSPECTION AND TEST PLANNING. Such planning shall encompass all areas of production including materials, components, subassemblies, end items, and preparation for delivery. Inspection and test plans shall include: a. Production flow and inspection stations beginning with receiving inspection.					
b. Characteristics to be inspected.					
c. Cross-reference to detailed inspection and test procedures.					
d. Sampling Plan.					
e. Coordination of inspection and tests to be witnessed by the customer					
f. Data to be submitted to customer.					
g. Nonconformance instructions.					
*4-13.3 INSPECTION AND TEST PROCEDURES. Written procedures shall be prepared for each inspection and test operation. They shall be readily available to inspection and test personnel at the applicable inspection station at the time of inspection and test. Each procedure shall include, as applicable: a. Identification of the article or material.					
b. Sampling plan or quantity to be tested or inspected.					
c. Detailed sequential instructions.					
d. Measurement characteristics and required measuring equipment.					
e. Acceptable tolerances, with reference to specifications or drawings.					
f. Acceptance and rejection criteria.					
g. Allowable adjustment, repair, or rework.					
h. Requirements for data recording and reporting.					
i. Disposition of article or material.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STND
4-14 QUALITY RECORDS AND INFORMATION FEEDBACK *4-14.1 The contractor shall generate and maintain records of all incoming, in-process, and final inspection and test data. These records shall indicate item identification, the actual measurement or test result, amount inspected or tested, amount acceptable, amount rejected, number and type of deficiencies, lot size, disposition, operator identification and date.					
*4-14.2 The contractor shall generate and maintain records to objectively document quality program activities. Such records include engineering changes, corrective actions, internal audits, calibration records, field reports, customer survey, and quality cost data.					
*4-14.3 Record retention policy shall be established for each type of record and its location. Records of inspection and tests performed on BPA contracts shall be maintained for a period of at least 3 years from the time of final delivery.					
*4-14.4 The quality program shall provide for the summary, analysis, and use of quality records as a basis for management action in each element of the quality program.					
4-15 NONCONFORMING MATERIAL *4-15.1 The contractor shall establish and maintain an effective system for controlling nonconforming material, including procedures for its identification, segregation, and disposition.					
*4-15.2 The contractor shall prepare and issue documents for each nonconformance containing as a minimum: a. A Serial Number.					
b. Identification of the nonconforming material.					
c. A description of the nonconformance, characteristic requirement, and tolerance.					
d. Function responsible for the nonconformance.					
e. Disposition of the nonconforming material: Scrap, rework, or repair, return to supplier, or submit to internal material review.					
f. Method of rework or repair.					
g. Reinspection and test method and results.					
h. Dates and signatures of authorized personnel.					
i. Identification of repeat nonconformance.					
j. Establish need and responsibility for corrective action to prevent recurrence of the nonconformance.					
*4-15.3 The contractor shall maintain the records of all nonconformance for trend detection, cause analysis, and corrective action.					

ELEMENT	Comments	RATING			
		WORK REQD		ACCEPTABLE	
		VOID	IN-COMP	ADE-QUATE	OUT-STND
4-16 CORRECTIVE ACTION *4-16.1 The contractor shall establish and maintain a corrective action system to promptly detect and correct assignable conditions adverse to quality. Corrective action shall cover all areas of contractor operations and extend to all suppliers and deficiencies reported by users.					
*4-16.2 Each corrective action shall be executed according to the steps of the following closed loop with the results of actions compiled on a separate document for this purpose: a. Notification of function responsible for deficiency.					
b. Determine extent and causes.					
c. Establish preventive actions.					
d. Rework of existing product in all conditions of completion.					
e. Followup to assure completion of corrective action.					
f. Review of effectiveness.					

Additional comments (please indicate cross reference code)

SERI

APPENDIX D

CONSOLIDATED EDISON COMPANY QUALITY ASSURANCE LEVEL MATRIX

(SPECIFICATION QA-7100)

SERI

QUALITY ASSURANCE LEVEL COMPARISON

	A	B	C	D
I Quality Program Management				
Organization and Program - Requires a quality assurance organization and program which provides controls in the following areas:				
Design	x	x		
Manufacture	x	x	x	
Material Procedures	x	x	x	
Inspection	x	x	x	x
Special Quality Assurance Plan - Requires a special plan to cover state-of-the-art extensions.	x			
Quality Assurance Program Summary - Requires the Seller to submit a summary of his quality assurance program.	x	x	x	
Inspection Plan - Requires the Seller to submit an outline of the product inspection plan.				x
Quality Audits - Requires Seller to conduct quality audits and permits Con Ed and its authorized representative to audit the quality effort.	x	x	x	x
Procedures - Requires written procedures to implement the QA program.	x	x	x	
Work Instructions - Requires written work instructions to supplement engineering drawings and specifications.	x	x		
Records - Requires Seller to submit a list of records and retention period for these records.	x	x	x	x
Document Control - Requires Seller to assure the adequacy and completeness of all documents and changes thereto.	x	x	x	
Corrective Action - Requires the Seller to maintain a documented system to detect and correct conditions which affect the quality of the equipment.	x	x		
II Design Control				
General System of Control - Requires Seller to establish methods for controlling design activities to assure that design criteria, codes, standards, etc. are defined and correctly translated into specifications drawings, procedures, and instructions.	x	x		

	A	B	C	D
II Design Control				
Design Criteria - Requires Seller to define the scope of effort needed to develop and control design criteria. Requires identification of new or unproven designs, material and standards in Seller's quotation.	x	x		
Special Design Review Procedure - Requires Seller to state special design review procedures to be used in areas where a state-of-the-art extension is required.	x			
III Material Control				
Procurement Source - Requires Seller to evaluate and control procurement sources to assure that material meets purchase order quality requirements.	x	x	x	
Procurement Documents - Requires a system to review procurement documents prior to release to assure incorporation of quality and technical requirements.	x	x		
Procurement Inspection - Requires an inspection system for purchased articles to verify conformance to applicable requirements.	x	x	x	
Raw Material Control - Requires Seller to identify and validate certifications received from suppliers of raw material.	x	x	x	
Limited Life/Age/Environment Control - Requires the Seller to implement a system to control materials having limited storage life requirements.	x	x	x	
Con Edison-Furnished Property - Specifies requirements for the use and care of Con Edison-furnished material.	x	x	x	
IV Production Control				
Material Identification and Control - Requires the Seller to maintain a system to identify and control material during manufacture to insure that only accepted materials are used.	x	x	x	
Manufacturing Control - Requires the Seller to plan and document a program to assure that each phase of fabrication, processing and assembly meets the requirements of applicable drawings, specifications, procedures, and work instructions.	x	x	x	

QUALITY ASSURANCE LEVEL COMPARISON (Cont'd)

		A	B	C	D
IV	**Production Control (Cont'd)**				
	Manufacturing Inspection Control - Requires Seller to maintain an inspection system during manufacturing operations.				x
	Handling - Requires the Seller to maintain facilities and procedures adequate to prevent damage to equipment, substitution, loss or quality degradtion.	x	x	x	x
	Special Processes - Requires Seller to identify processes requiring controlled applications in his QA program.	x	x	x	
	Packaging & Shipping - Requires Seller to maintain a system to control packaging and shipping operations.	x	x	x	x
	Tooling Accuracy - Establishes requirements for checks of accuracy of manufacturing tools, gages, jigs, and fixtures.	x	x	x	
	Inspection, Measuring and Test Equipment - Establishes requirements for use, care, and periodic calibration.	x	x	x	x
	Training and Certification of Personnel - Requires Seller to define work and inspection operations which require special training and/or certification of personnel.	x	x	x	
V	**Assurance of Conformance**				
	Con Edison Approvals - States that Con Edison approvals do not relieve Seller of the responsibility for furnishing end products meeting all requirements of the contract, and that changes to documents previously approved by Con Edison require approval.	x	x	x	x
	Inspection by Sampling - Permits use of sampling inspections. Requires Seller to include sampling plans in his QA program summary.	x	x	x	x
	Inspection Status Identification - Requires a system to identify the inspection status of all articles.	x	x	x	x
	Incomplete and Nonconforming Items - Establishes requirements for disposition of incomplete and nonconforming articles.	x	x	x	x

QUALITY ASSURANCE LEVEL CONPARISON (Cont'd)

		A	B	C	D
V	Assurance of Conformance (cont'd)				
	Corrective Action - Requires Seller to promptly correct conditions which have or could result in production of nonconforming items.	x	x	x	x
	Con Edison Notification - Requires Seller to respond promptly to Con Edison's request concerning deficiencies found in delivered items.	x	x	x	x
	Final Inspection and Test - Requires Seller to define the extent of final inspection and test in his QA program or inspection plan, and to conduct all inspections and tests prior to submittal to Con Edison.	x	x	x	x
	First Article Inspection - Establishes requirements for a first article inspection when required by the purchase order.			x	x

APPENDIX E

ANNOTATED BIBLIOGRAPHY

Barton, S. P.; Tapper, D. N. 1978. "Designing Turbine Generators for High Availability Power Plants." Presented at the Westinghouse Electric Corporation Steam Turbine and Generator Technology Symposium; Philadelphia, PA; 4-5 October 1978.

This paper describes the availability and design assurance techniques Westinghouse uses for the design of turbine-generators intended for power plants with overall plant availabilities in excess of 90%. The application of these techniques is discussed for: making preliminary availability estimates; designing new generic subsystems; developing turbine-generator systems for contract applications; and performing service related activities.

Baumgardner, J. S. 1980. "Determination of a Generation Expansion Planning LOLP Design Criterion." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

This paper presents the results of a comprehensive generation system reliability study to determine a loss-of-load probability (LOLP) design criterion for the Florida Power Corporation System. This paper also presents the results of the investigation into the relationship between a daily LOLP and an hourly LOLP for the Florida Power generation system.

Bonneville Power Administration, 1977 (3 Feb.). Quality Program Requirements. Portland, OR.

This specification establishes requirements for a quality program that shall be developed and maintained by the contractor to ensure that materials, products, and service are in compliance with the requirements of related contracts.

Brinkmiller, F. J.; Coogan, F. C. 1980. "A Corporate Approach to Reliability in an Electrical Industry." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

This paper presents a unique approach to corporate reliability, availability, maintainability,and safety. Traditionally, such programs are developed by corporate staffs and passed down to the division level. The approach described here develops the program at the division level and reports results to the corporation. The paper discusses the development of the program, program description, and expected results of the program.

Chamow, Martin F. 1978. "A Matrix Technique for Reliability Evaluations." Presented at the National Electronics Conference; Chicago, IL; 16-18 October 1978.

This paper presents a new approach for evaluating reliability models based on digraphs and related matrix methods. The new results involve matrices that contain fewer nonzero entries than are used by other methods. These are termed sparse matrices, and the main advantage gained from their use is a savings of computation effort.

Chamow, Martin F. 1978 (Apr.). "Directed Graph Techniques for the Analysis of Fault Trees." IEEE Transactions on Reliability. Vol. R-27 (No. 1).

Some of the difficulties encountered with previous fault tree valuation methods are avoided by using the methods described in this paper. The new methods involve using directed graphs (digraphs) and related matrix methods and solutions for paths in a manner similar to that for conventional digraphs. Most of the attractiveness stems from the fundamental philosophy of speedily transforming the graphics into corresponding matrices. This puts the bulk of the solution effort into the mathematics where it belongs. The major benefit arises because the mathematical solutions are readily performed by standard matrix techniques, which can be implemented either manually or with the aid of a computer. The new methods have been used on various hypothetical logic combinations and actual fault trees of typical sizes.

Commonwealth Edison Company. Station Nuclear Engineering Department. 1978 (Dec.). Productivity Improvement Program Guide. Chicago, IL.

The purpose of this guide is to identify a plan of action for performing engineering analysis and implementing recommended corrective actions to reduce the recurrence of nonproductivity in nuclear generating stations.

Conrad, J. D., Jr.. 1979 (Mar.). Steam Turbine-Generator Quality Assurance: A Management Approach. Philadelphia, PA: Westinghouse Power Generation.

New management concepts are being used to coalesce advanced turbine-generator technology and innovative quality assurance concepts. This paper describes the system synthesized by Westinghouse to provide for disciplined achievement of goals during the entire turbine-generator life cycle; i.e., from contract negotiation through design, manufacture and operation to unit retirement.

Consolidated Edison Company. 1972 (Apr.). Quality Assurance Requirements, Specification QA-7100. New York.

The purpose of this document is to provide guidance in how to apply and use QA-7100 when specifying the quality assurance effort required of a seller during the development and manufacture of equipment for Consolidated Edison.

Cutting, J. C.; DelBueno, R. P.; Eckels, R.; Maruvada, S. N.; Chamow, M. F.; Lynch J. J. "The Influence of Component Redundancy on the Availability of Open-Cycle MHD Power Plants." Presented at the Fourth U.S./U.S.S.R. Colloquium on Magnetohydrodynamic Electrical Power Generation. 5-6 October 1978. Washington, DC.

This paper describes a continuing effort to identify methods of improving availability/reliability of open-cycle magnetohydrodynamic (MHD) power plants. Analytical and design studies have been performed that indicate that the use of redundant MHD topping cycle equipment can result in significant improvement in plant availability and/or reduced MTBF requirements for channels and combustors. Design considerations for rapid component replacement/repair have been incorporated into the study and a safety analysis is presently underway. Final results of the study will include an assessment of the impact of these cycle or equipment arrangements on the commercialization of open-cycle MHD.

Department of Energy. 1979 (Mar.). Performance Assurance Contractual Specification Guide. (Draft) Washington, DC: DOE.

This guide contains standardized performance assurance-related specifications for use in all major fossil energy projects. The specifications are general in nature and the format has been designed so the DOE project manager may select and/or tailor any element of these specifications to fit the unique needs of any project. The Performance Assurance Office of the Planning and Systems Engineering Division also is available for assistance in tailoring these specifications. A separate "stand-alone" specification has been provided for each performance assurance discipline.

Department of Energy. 1979 (Mar.). The Fossil Performance Assurance Procedures Handbook. (Draft) No. 2623-03-29 Washington, DC: DOE.

This handbook is to aid fossil energy contractors in preparing and aiding the DOE Project Managers in their review of performance assurance (PA) program plans and procedures. The handbook provides a systematic approach for the contractor to use in preparing his PA program plans and procedures which, when implemented, are expected to strengthen the fossil energy programs. The handbook contains self-standing procedures to aid in writing program plans for reliability, maintainability and availability, system safety, life-cycle costing, configuration management, and quality assurance. In addition, each program plan procedure is accompained by additional self-standing procedures, as required, to implement each program plan. Use of these procedures will assure that the contractor will, when generating or modifying his supplied requirements, satisfy his basic obligation to provide an effective and economical performance assurance program.

Department of Energy, Fossil Energy Programs. 1979 (Apr.). Performance Assurance Project Managers Manual. Washington, DC: DOE.

This document contains a description of performance assurance (PA) elements, functions, and disciplines. It describes what PA is, why it is needed, when it should be applied, and how it should be applied to various types of fossil energy projects. It also provides illustrations of the application of PA disciplines during the typical phases of a fossil energy project. It is addressed to the fossil energy project managers, their staffs, and appropriate contractors to aid them in ensuring the design, development, and implementation of performance assurance programs applicable to particular projects, thereby enhancing the potential for success of these projects.

Garver, L. 1975. (Apr.). "Electric Utility Planning Models." Presented at the Joint National ORSA/TIMS Meeting; Chicago, IL. April 1975.

This paper introduces several electric utility planning models currently being used in long-range generation and transmission expansion studies.

Probability and optimization methods, now associated with operations research, were considered for utility problems as far back as 1933. Today these methods are applied to a broad range of probems, which in the planning area include setting generation reserves, simulating utility operation and synthesizing plans for generation and transmission expansion. The difficulties, successes, and current trends in these applications are discussed in this paper.

Holmes & Narver, Inc. 1978 (Mar.). Power Plant Data Systems. Palo Alto, CA: Electric Power Research Institute.

Several data systems now exist that collect and report certain kinds of data from operating units. This study was undertaken to determine what kind of power plant data are needed and how the information can best be provided. More than 150 people in 35 organizations were interviewed. The results of several industry/government meetings on the subject of data were reviewed. All known existing data systems were examined. Several data systems serving other industries were also studied to search for methods useful to the collection and dissemination of generating unit data. This final report summarizes the data needs of the power industry and the requirements of government agencies. The existing data gathering activities of the power industry and government agencies are described. Two plans for acquiring a single, national generating unit data system that would satisfy the needs of the power industry and the requirements of government agencies are presented.

Institute of Electrical and Electronics Engineers. 1979 (Mar.). Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity. Draft. Prepared by the Power Plant Productivity Definitions Task Force, Application of Probability Methods Subcommittee, Power System Engineering Committee. New York.

This standard was developed to overcome present difficulties in the interpretation of electric generating unit performance data from various systems and to facilitate comparisons among different systems. It should also make possible the future exchange of meaningful data among systems in the United States, Canada, and throughout the world. This document standardizes terminology and indices for reporting and evaluating electric-generating unit performance. Performance measures can generally be categorized into three groups—reliability, availability, and productivity.

Institute of Electrical and Electronics Engineers. 1979. Recommended Practice for Design of Reliable Industrial and Commerical Power Systems. Standards Project No. 493. New York.

The objective of this book is to present the fundamentals of reliability analysis as it applies to the planning and design of industrial and commercial electrical power distribution systems. The text material is primarily directed toward consulting and plant electrical engineers. The material in this book should enable engineers to make more use of quantitative cost versus reliability trade-off studies during the design of industrial and commercial power systems. Included are: basic concepts of reliability analysis by probability methods, fundamentals of power system reliability evaluation, economic evaluation of reliability, cost of power outage data, equipment reliability data, and examples of reliability analysis. In addition, discussion and information are provided on: emergency and standby power, electrical preventive maintenance, and evaluation and improvement of reliability of existing plants.

Klein, William E. 1980. "Modified Aerospace Reliability and Quality Assurance Method for Wind Turbines." Presented at the Annual Reliability and Maintainability Symposium; 22-24 Jan. 1980.

This paper describes the safety, reliability and quality assurance (SR&QA) approach developed for the first large wind turbine generator project, MOD-QA. The SR&QA approach had to ensure that the machine would not be hazardous to the public or operating personnel, would operate unattended on a utility grid, would demonstrate reliable operation and would help establish the quality assurance and maintainability requirements for future wind turbine projects. Since the ultimate objective of the wind energy program is to provide wind power at a cost competitive with other energy sources, the final SR&QA activities were to be accomplished at a minimum of cost and manpower. The final approach consisted of a modified failure modes and effects analysis (FMEA) during the design phase, minimal hardware inspections during parts fabrication, and three simple documents to control activities during machine construction and operation. This low cost approach has worked well enough that it should be considered by others for similar projects.

Krasnodebski, J.; Bartko, I. "How to Manage Design to Assure Quality Operations and Construction Feedback to Design." Presented at the Fourth Annual National Conference on Nuclear Power. Washington, DC; 10-12 Oct. 1977.

The nuclear power industry needs to design more timely and comprehensive feedback of operational and construction experiences. This paper reviews nuclear industry information systems in the United States. The organization of the Design and Construction and Operations Branches of Ontario Hydro, the quality engineering program, and responsibilities for information feedback are described. Application of information feedback to various design tasks is discussed. Prerequisites for component data collection systems that will provide the required information efficiently are described. The limitations of existing systems are briefly reviewed and suggestions for improvements made.

Krasnodebski, J.; Christians, J. 1977. "Reliability and Maintainability in Design of Power Stations." Presented at the Availability Engineering Workshop sponsored by the Electric Power Research Institute; Albuquerque, NM; October 1977.

This paper describes the development of a Reliability and Maintainability (R&M) engineering program and its application to the design of Ontario Hydro thermal power stations. The effect of the unavailability of these stations on the reliability of the power system and resulting cost are described. The R&M program and application of the various R&M design tasks are outlined. Allocation of availability goals, application of reliability analysis, design reviews, maintainability program, data collection, R&M activities in equipment procurement, and R&M training are discussed.

Krasnodebski, J.; Ravishanker, T. J. 1979. "Reliability Through Effective Specifications and Programs." Presented at the 1979 Reliability Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

This paper briefly reviews Ontario Hydro's Reliability and Maintainability (R&M) Program in designing generating stations and develops the need for adequate specification of equipment R&M requirements. The R&M program and tasks required of architect engineers (AE) and suppliers are outlined. Experience in carrying out the program is reviewed and approaches to increase effectiveness of both supplier and AE effort are suggested. R&M costs and their effect on equipment life-cycle cost and supplier income are also discussed.

Lawson, J. W.; Anderson, D. R. 1979. "Reliability Cost Benefits: A Utility Operations Viewpoint." Presented at the 1979 Reliability Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

This paper describes an approach to measuring and evaluating the performance of fossil- and nuclear-generating units and components with a view to instituting improvements based on relative economics. Examples of cost/benefit studies and their application are given.

Maruvada, S. N.; Ideise, K. E.; Charnow, M. F. 1978. "Failure Rate as a Design Parameter: Possibilities and Limitations." Presented at the 1978 Annual Reliability and Maintainability Symposium. Los Angeles, CA; 17-19 Jan. 1978.

This paper examines the availability performance of a fossil-fired generating unit taking into account several derated states. The probabilities of being in the up, down, and various derated states are computed using state space techniques and a derived measure of unit performance. The sensitivity of this measure of performance to the failure and repair rates of major components is obtained. The results can be used to aid decision making during the design of a power generating unit to obtain the most cost-effective reliability improvement.

Multhaup, H. A. 1980. "Design for Reliability and Maintainability: Life-Cycle Cost Minimization." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

The basic objective of the life-cycle cost analysis in this paper is to integrate all aspects of the reliability engineering function into a decision-making math model that is closely aligned with the end-use goals of gas turbine users. It allows a more rational global view relative to the establishment of R&M goals and requirements. This total economic analysis, however, requires quantitive inputs from many organizations on both sides of the manufacturer/user interface.

Niebo, Ronald J. 1979. "Transition of Equipment Availability Data System to NERC." Presented at the 1979 Reliability Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

This paper reviews the current status of the data base since its transition to NERC on 1 January 1979. The data base rebuilding program initiated by

NERC, the new data reporting procedures manual, and anticipated changes to the data base are outlined. The initial reactions of the utilities and the Department of Energy regarding the transition and subsequent revisions to the data base are also discussed.

Poole, David N. "Performance and Reliability: A Many Faceted Component Improvement Program." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

This paper discusses EPRI's reliability and performance improvement program of both new and existing fossil-fueled steam power plants. The program addresses every major problem area that has been identified to ultimately improve reliability. The program, as currently established, deals with five separate but interrelated areas. They are turbine/generators, steam generators, plant auxiliaries, plant chemistry, and integrated plant. As currently designed, this program will cost approximately $50 million for the five-year period 1980-1984. Conservatively, the utility industry should accrue benefits of at least $20 billion over the following 20-year period as a result of these R&D efforts.

Ravishankar, T. J. 1980. "R&M Program for Gas Turbine-Generators in Nuclear Generating Stations." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

This paper describes Ontario Hydro's R&M program in procuring gas turbine-generator (GT) sets. A brief description of the functions of the on-site backup power supplies and their GT is given. A description of the approach used in determining the number of GT constituting the on-site backup power supplies and identification of their R&M requirements is then presented. The essential elements of the supplier's R&M program, communicated through the R&M clause in technical specifications, are described. This paper also describes Ontario Hydro's experience in contract monitoring and follow-up with three manufacturers on four contracts. Areas where difficulties were experienced and areas that require careful consideration are identified.

S. M. Stoller Corporation. 1978 (July). Consolidating Power Plant Data Systems. Palo Alto, CA: Electric Power Research Institute.

This report described the experience of several large industries with collecting and using equipment performance data in large complex systems and assessing the feasibility of consolidating power plant data bases. It discusses the results of interviews conducted with two utilities and six organizations outside the utility industry. It concludes that consolidation of data collection in a single organization would reduce the burden of reporting by the utilities and would improve the quality and availability of the data. Several potential improvements in the quality and scope of plant outage cause data are recommended.

S. M. Stoller Corporation. 1979 (Feb.). Power Plant Early Alert Reporting System. Palo Alto, CA: Electric Power Research Institute.

The early alert reporting system (EARS) as presented in this report collects information on significant generic failures in power plants and broadcasts the details of these failures in a timely manner to other utilities, architect engineers, and manufacturers in an attempt at avert similar failures in other plants. The need for such an alert system was identified in an industry study of power plant data systems sponsored by the American National Standards Institute (ANSI). As a result of this identified need, the Executive Committee of the Edison Electric Institute's Engineering and Operations Committee requested that EPRI undertake a study to define the scope and operating method for an alert system. This report contains the results of that study.

Stone & Webster Engineering Corp. 1979 (Apr.). Analysis of Utility Industry Data Systems. Palo Alto, CA: Electric Power Research Institute.

This project examines the usefulness of the three most prominent availability and reliability related data systems currently being supported by the electric power industry: (1) Equipment Availability Data System (Edison Electric Institute), (2) Operating Units Status Reports—Gray Books (U.S. Nuclear Regulatory Commission), and (3) the Nuclear Plant Reliability Data System—NPRDS (American National Standards Institute). The aim was to test completeness, accuracy, and utility of these data reporting systems by attempting to apply the data to power plant reliability and availability analysis. Results of some of the computations that can be made with existing data are provided together with cautions concerning their interpretation. The study indicates limitations and deficiencies in each of the systems. The basis for judging limitations and deficiencies was not necessarily what the data systems were designed to do, but their ability to supply data necessary to perform basic reliability and availability analyses applicable to power plants and their equipment. Recommendations are offered concerning actions necessary to enhance existing systems and actions that should be considered in developing any new data reporting system.

System Development Cooperation, 1978 (Mar.). Procedures for the Operation and Use of the Fossil Energy Equipment Data System (FEEDS).

This document provides operating procedures for the first phase of DOE's Fossil Energy Equipment Data System (FEEDS). The system is being established to provide for the collection, analysis, storage, and dissemination of equipment and material failure, availability, operability, and maintainability information generated through the operation of fossil energy plants.

Vanderzanden, W. R. 1980. "The Economics of Power Transformer Reliability-Improvement by Profit Incentive." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

The cost of buying a step-up power transformer is only the first cost incurred in owning the transformer. Utilities have long recognized that transformer losses are an important economic factor. Therefore, methods have been developed to calculate the value of losses over the life of a transformer, and these are added to the purchase cost. A major forced outage on a large power transformer can also have a large economic impact. The cost of repairing or replacing failed transformers with long

lead times is an important element of cost. Frequent report of transformer failure suggest the problem may be increasing. While the transformer has a forced outage, replacement energy must be obtained. Cascading outages represent a greater risk when a transformer is out of service. These factors also contribute to the additional transmission system and generation reserves needed to compensate for the increased system forced outage rate resulting from the transformer failure rate.

Vessley, J. E.; Cowdery, J. W. 1980. "RAM-A Management Challenge." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

The presentation examines the current needs and benefits of RAM (Reliability, Availability, Maintainability) programs from three different viewpoints, i.e., general public, customers, and stockholders. The FPL organization and approach in response to these needs is described. Specific activities, including data use, illustrate the effectiveness of this organization. The paper concludes with expected future activities.

Walters, R. J. 1979. "Realizing Reliability." Presented at the 1979 Reliability Conference for the Electric Power Industry; Miami Beach, FL; 19-20 April 1979.

At a time of fiscal restraint, it is important that good performance is achieved from new generating stations since this reduces system expansion costs and replacement energy costs to the utility. This paper shows that these costs can be defined in relationship to unit performance and then used to evaluate equipment tenders on an overall life-cycle cost basis. By this means, better assurance of future performance is obtained.

Zagursky, G. P.; Pillar, C. S. 1980. "A Systems Approach to Reliability Program Development and Implementation." Presented at the 1980 Reliability Conference for the Electric Power Industry; Madison, WI; 29-30 April 1980.

This paper discusses the techniques used by Florida Power & Light Company to develop and implement a practical and effective power generation reliability program. Although the overall reliability objectives were clear, the division of responsibility was not. In an attempt to manage this monumental effort, a systems approach was used to identify and separate the task into its basic elements for analysis and program development. The results produced a reliability team, complete with a program charter and functional department guideline documents for implementation.

Document Control Page	1. SERI Report No. TR-642-784	2. NTIS Accession No.	3. Recipient's Accession No.

4. Title and Subtitle	5. Publication Date
Evaluation of Conventional Electric Power Generating Industry Quality Assurance and Reliability Practices	March 1981
	6.
7. Author(s) R. T. Anderson, H. A. Lauffenburger	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	10. Project/Task/Work Unit No. 1092.00 11. Contract (C) or Grant (G) No. (C) (G)
12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered Technical Report 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report presents the results of a study of the quality assurance and reliability (QA&R) practices employed by the conventional electric power generating industry to provide a frame of reference for PV program QA&R activities. The power industry is, within the past several year, adopting many of the reliability/maintainability program elements originally applied in military and space programs. These efforts coupled with the more traditional quality assurance practices are resulting in substantial operating plant cost savings. Increased attention is being given to the incorporation of reliability requirements in specification for new plants and equipments, and in analytical techniques (FTA, FMEA, prediction, etc.) during system development. Recovery, analysis and reporting of field productivity performance data (availability, outage rates, etc.) is recognized as a key factor for reliability improvement with effort being pursued toward establishing a national data system. Many of the practices should be cost-effective when applied to PV program elements. Some can be readily implemented in the near term whereas others require adaptation and further evaluation prior to widespread use.

17. Document Analysis

a. Descriptors Availability ; Cost Benefit Analysis ; Electric Power Industry:T1 ; Evaluation:Q1 ; Outages ; Photovoltaic Power Plants ; Quality Assurance:Q1 ; Reliability: Q1 ; Specifications ; Systems Analysis ; Industry ; Power Plants ;

b. Identifiers/Open-Ended Terms Solar Power Plants

c. UC Categories
97d

18. Availability Statement	19. No. of Pages
National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, Virginia 22161	114 20. Price $6.50

Form No. 8200-13 (6-79)

☆U.S. GOVERNMENT PRINTING OFFICE:1981—777-084 / 27